MCDC REPORT

US INDUSTRIAL BASE DEPENDENCE/VULNERABILITY

PHASE II - ANALYSIS

NOVEMBER 1987

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US INDUSTRIAL BASE DEPENDENCE/VULNERABILITY

ANALYSIS

This is a report on the second of a two-part study of foreign source dependency/vulnerability conducted by the Mobilization Concepts Development Center. The first part of the study, which summarized the relevant studies on the subject, was reported on in US Industrial Base Dependence/Vulnerability, Phase I - Survey of Literature, December, 1986.

This report examines the circumstances under which a foreign dependency might become a vulnerability and develops a framework for determining priorities to deal with the foreign vulnerability issue. Three case studies which illustrate the three generic effects of foreign dependency are examined as are alternate remedies for mitigating identified vulnerabilities.

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US INDUSTRIAL BASE DEPENDENCE/VULNERABILITY

PHASE II - ANALYSIS

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Mobilization Concepts Development Center (MCDC) was tasked by the Mobilization Steering Group to examine the issue of US industrial base foreign dependency and foreign vulnerability. This is an issue that has received considerable attention both in and out of the government. The study was therefore divided into two phases. Phase I was a survey of the recent studies on the issue, reported on in US Industrial Base Dependence/Vulnerability, Phase I - Survey of the Literature. Phase I indicated that although there has been extensive study of various aspects of foreign dependency/vulnerability, most of this work has been initiated as a result of concerns over a single weapons system, a group of similar systems, or a single industrial sector. While this largely ad hoc approach to the study of foreign vulnerability has provided information on particular weapons and support systems, it has provided less insight into determining where to spend additional effort to identify critical vulnerabilities, or where best to spend funds that might be made available to deal with identified vulnerabilities. Phase II, this analysis, has therefore focused on three areas: 1) defining the nature of the foreign vulnerability problem, 2) developing a framework for identifying and assessing the degree of foreign vulnerability, and 3) suggesting some methods for dealing with identified foreign vulnerabilities.

The Nature of the Problem

The purchase of goods and services abroad should be viewed as both an opportunity and a potential problem. It is an opportunity in that the purchase of defense materiel from abroad provides access to materials and technology not available--or not available on favorable terms--in the United States. Foreign purchases, however, cause three further effects: (1) to the extent that the foreign sources are less reliable than domestic sources, continuous production flow is jeopardized; (2) domestic capacity is reduced; and (3) domestic technology is retarded. If we are to reap the benefits of access abroad, we must deal with these problems.

Dealing with these problems requires a means of prioritizing them. An initial step in this process is developing an understanding of the nature of the foreign vulnerability issue. Not everything that is sourced abroad, nor indeed everything for which the US has a foreign dependency, is a foreign vulnerability. There are important differences between these categories. Figure ES-1 illustrates our assessment of the differences existing between foreign sourcing, foreign dependency, and foreign vulnerability.

FIGURE ES-1

DEFINITIONS

FOREIGN SOURCE

Any source of supply, manufacture, or technology outside the United States or Canada

FOREIGN DEPENDENCE

• • • for which there is no immediately available alternative source within the United States or Canada

FOREIGN VULNERABILITY

• • • and whose lack of reliability and substitutability jeopardizes national security by precluding the production, or significantly reducing the capability, of a critical weapons system.

If foreign vulnerabilities are a subset of all the items sourced abroad, the initial effort must be on identifying the vulnerabilities. Given the large number of items that are sourced abroad, and the growing interdependence of the world economy, it is clear that the key to successfully dealing with foreign vulnerability is not identifying and eliminating all foreign sources, or even all foreign dependencies, but identifying and eliminating those dependencies that are indeed identified as vulnerabilities.

Types of Vulnerabilities

Our study also led us to separate our consideration of vulnerability into three different categories: "surge" and "mobilization" vulnerabilities, which exist principally in the production area, and "technology base" vulnerability, which potentially exists across the spectrum. The differences are important since different policies are required to deal with the different categories.

Framework for Analysis

We developed a framework for analyzing foreign vulnerability that included criteria for prioritizing system and material requirements under a range of national security contingencies, and provided insight into the circumstances under which a dependency can become a vulnerability and the relative degree of that vulnerability. Figure ES-2 illustrates that framework.

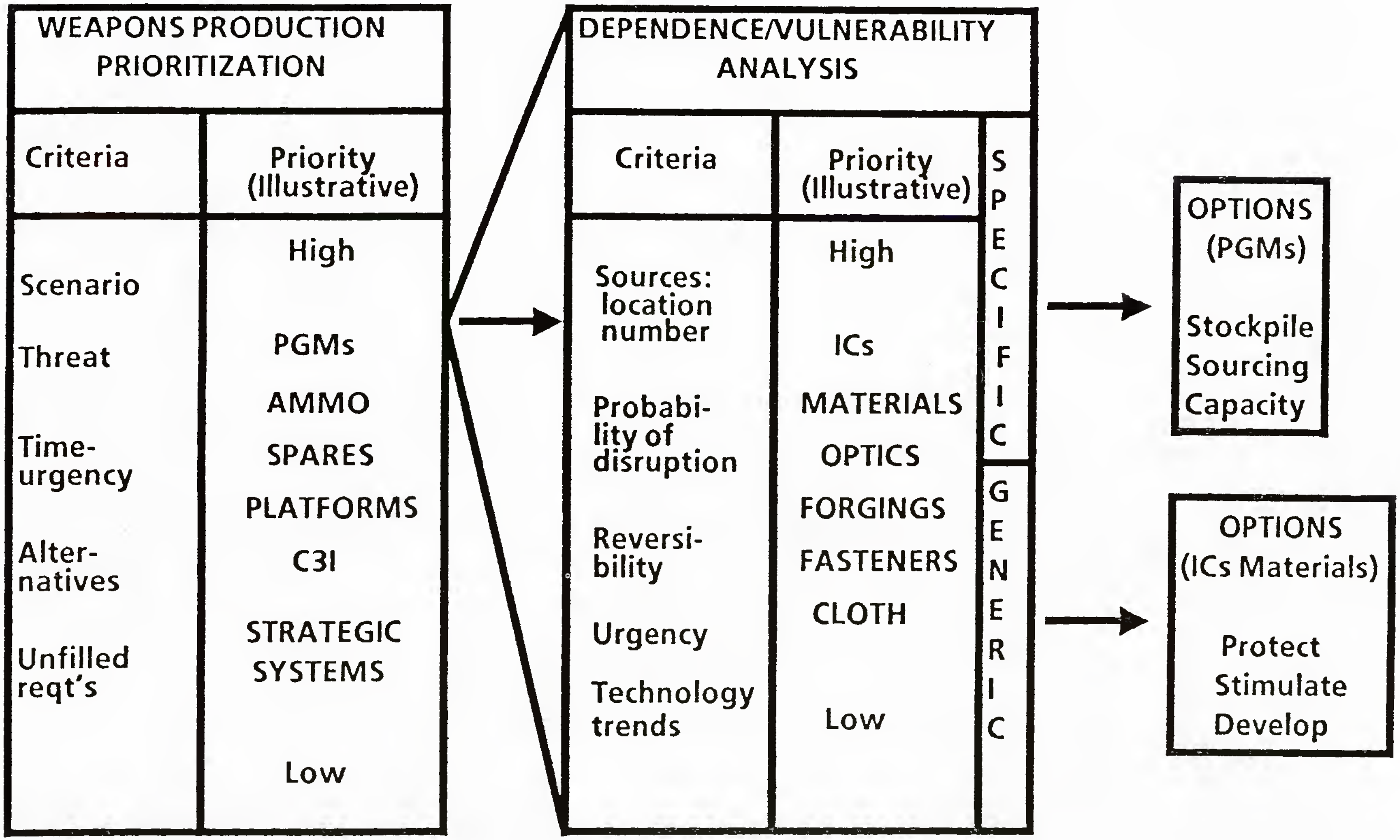
Case Studies

Sections Three, Four and Five contain three case studies of foreign source dependence, each focused on one particular aspect of the phenomenon.

Case one examines foreign source dependence in the production of Precision Guided Munitions (PGMs), and the attendant risk that an unanticipated cut off from foreign sources would jeopardize existing delivery schedules. This, indeed, is a real risk. Although only one or two percent of a typical PGM's value is added from overseas sources, any disruption in this flow would lead to a cessation of production lasting several months to a year. By and large, most foreign components represent parts which could also be made in North America as well (albeit at greater cost or extended qualification times). As such, a buffer stock of affected parts, of sufficient quantity, would be sufficient to bridge the potential gap between an overseas cut off and the resumption of supply from domestic sources (under emergency conditions). The cost of the buffer stock is estimated

FIGURE ES-2

CONCEPTUAL FRAMEWORK



at $15 million dollars to maintain current production schedules ($5 million more would cover surge requirements). This is less than what DoD spends in one day on PGM hardware itself.

Case two examines whether the existing stockpile of petroleum and nonfuel minerals is sufficient to cover military and essential civilian needs in the context of an extended war. Here, foreign source dependency is related to insufficient production capacity in the US (and the rest of North America). In this security contingency a substantial fraction of the GNP is devoted to weapons expenditures, paid for, in part, by reduced civilian purchases of consumer durables and new housing. The conclusions are guarded. For energy, current North American capacity is sufficient to support the economy with only a modest reduction in motor vehicle consumption. However, as the low price of oil continues to depress both production and conservation, the reduction in consumption needed to get by in a war grows with every passing year. For minerals, and their associated metals, the National Defense Stockpile has sufficient assets to fill wartime needs after a modest adjustment in inventories. Some minerals (e.g. tantalum, columbium) would be in short supply, but sales of excess materials (e.g. silver, base metals in general) would more than suffice to finance purchases.

Case three examines the potential consequences of losing America's technological edge in the production of integrated circuits. Having to depend on overseas sources for our weapons technology would delay the introduction of state-of-the-art devices into new weapons systems. In some cases the best devices may be unavailable due to commercial reasons, political reasons, or simply the reduced desire of overseas sources to adapt their products to the needs of the US military. However, evidence indicates that the reported demise of the US integrated circuit industry is premature. Although the domestic industry has lost money over the last two years, it is recovering. Imports from Japan, while well-publicized, have no greater share of the US market then our exports have in theirs. But DoD is correctly concerned over future trends given the industry's structural weaknesses. To that end it may deploy a variety of tools from supporting R&D (through its own programs, through national laboratories, through industry consortia), to purchase guarantees, the reform of its own purchase practices, or other financial arrangements. Key to DoD's efforts would be the development of an industrial strategy for technologically troubled sectors, preferably before they become obvious problems.

Alternative Strategies

Some alternative strategies were suggested to deal with the foreign dependency/vulnerability issues in each of the cases. To be effective, such policies need to be developed within an overall foreign vulnerability strategy. The study grouped generic options into three strategy categories which we called: Status Quo, Buy American, and Buy World.

Status Quo

The Status Quo is a strategy by default. It is the current mixture of policy directives and guidance that attempts to emphasize preservation of the defense industrial base, arms cooperation with allies, and competition all at once. Told to preserve the domestic industrial base, a program manager tries to buy from domestic sources; told to maximize arms cooperation with allies, a program manager explores cooperative development and production arrangements with NATO allies; and told to emphasize competition, a program manager seeks the widest range of prospective bidders on his program--including Japanese, Israeli, Korean, Brazilian, et cetera. The program manager clearly cannot meet all three objectives at once.

Buy American

A requirement to purchase all items of defense materiel from US or Canadian sources (The North American Defense Industrial Base) would reduce the chances of disruption during a crisis. It would remove the threat of foreign competition from domestic suppliers of services and equipment, and would increase the demand for their products. Domestic suppliers could increase both their DoD market share and their price to the government. The resulting increase in the costs of defense materiel would represent the price of the insurance premium necessary to avoid disruptions in production during crisis. The technology available under a Buy American strategy would be the best domestic technology--which, in some cases, will not be the best in the world. Cooperation among US and Allied Industrial Bases would be essentially precluded and weapons standardization would be difficult. Allies and other nations would feel pressured to adopt similar restrictive measures thereby reducing the market for US products.

Buy World

A strategy of Buy World lies at the other end of the spectrum. Following this strategy, a requirement to set quality standards and then purchase DoD materiel from the lowest-priced sources that meet those standards would ensure DoD obtained its requirements at lowest cost. The technology available under such a strategy would be the best in the world. To the extent that purchases under this strategy from insecure or potentially inaccessible sources, they would be subject to disruption during a crisis. Less competitive domestic firms would lose sales and, unless they became more competitive, could go out of business. The United States would probably find itself with a much larger foreign vulnerability problem.

Developing an Acceptable Strategy

The trade-offs among access to the most efficient producers, cost considerations in periods of constrained budgets, the international political advantages of armaments cooperation, the health of the domestic industry, and security of supply are easy to see and yet difficult to manage. Clearly there are choices more interesting than the pure strategies of Buy American, Buy World, or the current default strategy of Status Quo. A strategy designed to take advantage of all free-world resources, while managing risks entailed in foreign purchases, is clearly called for and such a strategy is outlined below.

Maximize Opportunity, Manage Risks

A mixed strategy would be designed to take advantage of the technical and production facilities of the US, its Allied and friendly nations, but would require that the United States manage the risks inherent in purchasing materiel from sources outside the United States and Canada. The policy elements of such a strategy are:

- Set quality standards
- Accept bids from all qualified sources
- Manage worst risks
- Protect and enhance access
- Reciprocal Allied purchase decisions

Setting quality standards and accepting bids from qualified sources are components of all the options discussed above. Risk mitigation and access enhancement result from a program that prioritizes the risks and pursues policies to deal with them--including, where we feel it necessary, buying only in America. Protecting and enhancing access to the foreign scientific and industrial bases are essential because increasingly useful technology will be developed abroad--no matter which policies are pursued. Unless the United States includes policies aimed at maintaining access to that technology in our overall strategy, we may be forced to forego the most advanced technology in some fields. Pursuing such a strategy costs money and demands a long term commitment. However, it appears fundamental to our future national security.

Conclusions

Foreign vulnerabilities clearly exist. However, they are a small subset of all foreign sources. They can be identified and when they are, actions can and must be taken to deal with them.

Vulnerabilities that jeopardize surge and larger-scale crisis production are problems for contingencies judged to be of low probability, but very high risk--such as war with the Soviet Union. Further, these vulnerabilities become exploitable under low probability circumstances within these low probability contingencies--extended and near-total cutoff of foreign sources. Under these circumstances the question becomes: How much of an insurance premium are we willing to pay to insure continuous production in these scenarios? Some policy options, stockpiling a limited number of parts available only from unstable sources for example, entail reasonable costs. Others, a pure Buy American strategy, for example, are very expensive.

The vulnerabilities associated with the security of the US technology base, unlike those associated with continuous production, exist across the conflict spectrum. These vulnerabilities are more difficult to deal with because they affect weapons systems and capabilites that do not yet exist. More generalized policy options--support for scientific and technological research and education--are called for here.

Finally, in dealing with this important issue, it is necessary to keep in mind that the US is part of an alliance and draws strength from that alliance. Although disruptions are possible due to military or political causes, Allied support is judged likely in most cases. Planning for no support from our allies is a waste of resources we cannot afford. Rather than thinking about foreign sources as a problem, one should think about foreign sources as a resource, one requiring actions to hedge against the possibility of disruption, but a valuable resource nonetheless.

INTRODUCTION

The Mobilization Concepts Development Center (MCDC) was tasked by the Under Secretary of Defense for Policy to examine the issue of US industrial base foreign dependence and vulnerability. This is the second of a two part effort to complete that task.

Concern about this topic is not new. On 5 December 1791, Alexander Hamilton sent the Speaker of the House of Representatives his "Report on Manufactures". The introduction read in part:

> The Secretary of the Treasury in obedience to the order of ye House of Representatives, of the 15th day of January 1790, has applied his attention, at as early a period as his other duties would permit, to the subject of Manufactures; and particularly to the means of promoting such as will tend to render the United States, independent on foreign nations, for military and other essential supplies.

While not encompassing all studies since 1791, the first phase of this effort reviewed more recent studies of the foreign dependency issue. That literature review was published by MCDC in December 1986.

This second phase addresses foreign dependency as an extant phenomenon, one that may be perceived at the same time as both an opportunity and a problem. Purchase of defense materiel from abroad provides access to materials and technology not available --or not available on favorable terms--in the United States; hence, these purchases represent an opportunity for the Defense Department. Foreign purchases, however, cause three further effects: 1) to the extent the foreign sources are less reliable than domestic sources, continuous production flow is jeopardized; 2) domestic capacity is reduced; and 3) domestic technology is retarded. These three effects are examined here using case studies of precision guided munitions, industrial materials and integrated circuits, respectively.

This phase of the MCDC effort consists of six sections: Section One examines the circumstances under which a foreign dependency might become a vulnerability; Section Two develops a framework for determining priorities to deal with the foreign vulnerability issue. Building on this framework, Sections Three, Four and Five are three case studies which illustrate the three generic effects of foreign source dependency. Section Six examines alternative remedies for mitigating identified vulnerabilities and presents a summary and conclusions.

SECTION ONE

Foreign Dependency Versus Vulnerability

Definitions

A first step in understanding the vulnerability problem is developing a common understanding of the elements of sourcing, dependency and vulnerability. Definitions developed for this study are shown in Figure 1. The figure further illustrates that foreign dependencies are a subset of foreign sources; and vulnerabilities--those dependencies demanding action--are a subset of foreign dependencies.

The definition for foreign source, as used by MCDC, is modified somewhat from previous definitions to include Hawaii and Alaska, as well as the continental United States and Canada, as secure US sources.[1] Examples of foreign sources include: the purchase of optical equipment for military systems from Germany and the Far East, acquiring rocket motor casings from the United Kingdom, and the use of semiconductors built by US firms, but packaged in Asia.

As Figure 1 notes, a foreign dependency differs from a foreign source in that there is no immediately available alternative source within the United States or Canada. For example, there is currently no US or Canadian source for the rocket motor casings built by the Royal Ordnance Factories in the UK for certain US precision guided munitions.

Finally, vulnerabilities are an even smaller sub-group for which there is no immediately available source within the United States or Canada and no ready substitute, and whose loss would have a negative effect on US national security by precluding the production of a critical weapons system, or resulting in a significantly less capable weapons system. Examples of potential vulnerabilities that have been identified in past studies include selected microelectronic items such as radio frequency (RF) tran-

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1. Given current transportation capabilities and the fact that an attack on either the Hawaii or Alaska is a direct attack on the U.S., we see no reason to exclude them from the U.S. base.

FIGURE 1

DEFINITIONS

FOREIGN SOURCE

Any source of supply, manufacture, or technology outside the United States or Canada

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FOREIGN VULNERABILITY

• • • and whose lack of reliability and substitutability jeopardizes national security by precluding the production, or significantly reducing the capability, of a critical weapons system.

sistors from Nippon Electric Corporation (NEC) of Japan and materials such as ceramics for electronic packages.[2]

There are several points to be made about these definitions. First, while the definitions of foreign sources and foreign dependencies are relatively straightforward (foreign source and foreign dependency are yes/no issues, and fairly simple to determine), the determination of a vulnerability is far more complex. Determining whether a vulnerability exists depends on a number of factors including: the criticality of the item, the number of possible sources, the location of those sources, and a host of other factors. To deal with this complexity, MCDC has developed a set of criteria to be considered in determining whether a foreign dependency may equate to a vulnerability.

Second, as Figure 1 indicates, not everything that is sourced abroad, nor indeed all foreign dependencies, represent vulnerabilities. This observation is absolutely critical to properly understanding foreign vulnerability and developing policies to deal with identified vulnerabilities. The key to successfully dealing with vulnerability is not identifying and eliminating all foreign sources, or even all foreign dependencies, but identifying and eliminating those dependencies that are indeed vulnerabilities.

Types of Vulnerability

A foreign dependency becomes a vulnerability, as Figure 1 shows, if it precludes the production, or significantly reduces the capability, of a critical weapon or support system. This can occur under several conditions and might be usefully considered in three different categories. Two of these relate principally to production under time constraints, while the focus of the third category is on the reduction of the overall capability of the system in question.

The first, "surge vulnerability," has prompted the most concern in military planning circles. Surge involves the accelerated production, maintenance, and repair of selected critical items to sustain conflict and/or equip the active force.[3] The surge period lasts on the order of 6 to 12 months

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2. Applied Concepts Corporation and the Analytical Sciences Corporation, A Study of the Effect of Foreign Dependency, 15 October 1985, hereafter known as the Joint Logistics Commanders' (JLC) Study (for the Air Force Logistics Command).

3. The Analytic Sciences Corp., Improving Intergovernmental Mobilization Planning: Preliminary INDCON and PERSCON System, Vol 2: INDCON/PERSCON TABLES, 1 Oct. 1986.

and involves the initial ramp-up of production that occurs in a period short of a declared national emergency. A surge foreign vulnerability exists when a foreign dependency has a high probability of preventing this rapid increase in the given time-frame by precluding production, or because key components of a system might be unavailable, thus causing those systems that are fielded to be less effective than required, and thus jeopardizing the planned mission.

The second type of vulnerability is "mobilization vulnerability" and is related to either full or total mobilization and involves: 1) a period from 12 months to years (the duration of the conflict), and 2) the production of the total range of weapons and supporting systems to conduct a conflict.[4] A vulnerability exists if there is a high probability that the production of key weapons and supporting systems, or a range of systems, will be prevented or slowed, thus jeopardizing the capability of the United States to support its national defense objectives. During World War II the US was cut off from a variety of raw materials that slowed the production of arms and munitions.[5]

The third type of vulnerability, "technology base vulnerability" is in one sense a relatively new concern, but in another, has been a principal concern of the United States since the end of World War II. The United States has periodically expressed concerns over the possibility of a technological surprise by the Soviet Union that would drastically alter the military balance. The new concern, however, is that the technology will be developed not in the Soviet Union, but in a third country (Japan or in Western Europe) and that the US will not have sufficient access to that technology in either war or peacetime. Thus, the technology base vulnerability concern is not over orderliness of the production, but over access to the most advanced technology for development and production of weapons. Examples of this type concern are contained in: 1) the recent report by the Defense Science Board on Semiconductor Dependency,[6] 2) the broader concerns over the development of new materials that might have application to weapons or support systems, and 3) the concerns over developments in scientific areas with possible application to directed energy weapons. A technology base dependency exists

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4. Ibid.

5. R. Elberton Smith, The Army and Economic Mobilization, United States Army in World War II, Office of the Chief of Military History, Department of the Army, Washington D.C., 1959.

6. Defense Science Board, Report of the Task Force on Defense Semiconductor Dependency, 31 December 1986.

when the United States must acquire advance technology for critical weapons development from a foreign source (integrated circuits from the Japanese, new armor material from the British). A technology base vulnerability exists when there is a high probability that the US will not have sufficient access to the essential technology and that the lack of access to that technology will prevent the United States from developing and producing weapons and support systems critical for maintaining deterrence or winning a war. While this type of vulnerability may ultimately have an effect on manufacturing capabilities and would appear to heighten surge and mobilization vulnerabilities, its most important effect is, as noted earlier, the reduction of the technological edge that the United States has argued is key to confronting the quantitative superiority of the Soviet Union.[7]

While the problem of a potential technology base vulnerability would appear to be a far more pervasive and longer term problem than either the surge or mobilization vulnerability problems, there are reasons to be sanguine about the extent of the problem and its real effects. The US was dependent on foreign sources for a variety of essential technologies during World War II including key developments in radar and jet engines, and critical assistance on the development of atomic weapons. It was only after World War II that the US, with a relatively undamaged scientific and industrial base, assumed a clear technological lead in weapons technology. There is no evidence that the common interests that drew allies to the US in World War II, or have been the basis for alliances in the post-war period, will necessarily be any more fragile than in the past, or that the US will be less likely to have continued access to Allied technology. However, there are very good reasons for tracking technology at home and abroad and for maintaining a competitive capability in technology areas so that it is both possible to evaluate the technologies that are being developed and their potential application to military systems, and to avoid becoming so dependent on technology that the supplier can have an undue

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7. This technological edge is important across the weapons and conflict spectrum and discussed in military documents such as the Battlefield Development Plan 1985 (U), TRADOC, U.S. Army, 8 January 1986 (SNF); and general publications such as Andrew Pierre, ed, The Conventional Defense of Europe: New Technologies and Strategies, Council on Foreign Relations, 1986.

influence on the political and military policy of the United States.[8]

8. This was noted as a potential problem by several specialists with regard to Japan. Their argument was that it was not necessary to be ahead of the Japanese in all technical areas, but it was necessary to be competitive, sometimes ahead, sometimes behind, but always in the race, in most developments if long term access to technology is to be maintained.

SECTION TWO

Framework for Determining Priorities

Framework Development

Although much work has been done on various aspects of foreign dependency and vulnerability, the literature reveals that this work has usually been initiated as a result of concerns over a single system or group of systems rather than a part of a coordinated research effort. While this ad hoc approach to the study of vulnerability provides information on particular weapons and support systems, it provides little insight into determining either where to spend additional study effort to identify critical vulnerabilities or where to spend the limited funds that might be made available to deal with identified vulnerabilities. The sheer size of the problem (encompassing the entire range of weapons and support systems that the US must deploy for its security), and the associated large data gathering requirement essential to assess the issue, mandate a more systematic approach.[9] Such an approach must consider the range of potential conflicts and the systems required in those conflicts in a way that will allow weapons systems to be put in priority for analysis and action.

Considering the Trade-offs

Vulnerabilities associated with foreign sources of supply do not appear to be problems that can be solved by a policy of either total reliance on the US industrial base or a laissez faire approach to industrial and technological trends. There are trade-offs to be considered. While there are reasons to be concerned about becoming too dependent on overseas sources, there are benefits to be derived from these sources as well. The task facing United States decision makers is to develop policies that lower the overall risks that are seen to accompany an increasingly interdependent world, while taking advantage of the benefits of an increased scientific and industrial base within the free world. Further, these trade-offs have to be considered in the context of overall US national security requirements, not solely in the context of procurement policy. Thus, the role of the alliance and the effect of a more rational approach to defense in promoting overall security are important policy determinants.

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9. The framework developed here builds on some of the concepts developed by J. Scott Hauger et. al., in the JLC Study.

Scenario Dependence

Concerns about vulnerability have tended to focus on a single scenario--a long, conventional war with the Soviet Union. This has had a number of effects. One of these has been that some analysts, who consider the probability of this scenario to be very low, have not been particularly interested in the foreign dependency/vulnerability issue. A second effect has been that systems not normally identified as essential to a long conventional war with the Soviet Union are often not considered as potential problems. For example, the key deterrent role that nuclear weapons would play in a long conventional war between the US and the Soviet Union, their potential limited use in such a conflict, and the potential need for expansion and support of these forces in a crisis have been largely ignored, as has any concern over surge and mobilization vulnerabilities related to these forces. Further, the whole issue of the technology base as it relates to maintaining a viable deterrent force is potentially ignored in the concentration on this single scenario and the effects of surge and mobilization vulnerabilities.

The Need for Alternative Scenarios

Since the United States must prepare to deal with a number of contingencies and needs a range of forces, it appeared useful to examine a range of contingencies rather than concentrate on a single scenario. Thus any framework for assessing foreign dependencies and potential vulnerabilities must include a range of national security contingency scenarios that can be analyzed in sufficient detail to determine US and Allied force requirements, their corresponding materiel requirements, and thus their production requirements. The scenarios considered in this study are listed in Table 1.

These scenarios range from what we defined as the day-to-day peacetime deterrence activities (with current force deployments, levels of military alert, and operational activities) to the highest levels of global nuclear conflict and include consideration of war termination, and demobilization and reconstitution of the country. The scenarios are generic in that they do not describe an exact activity, but types of activities that could occur. For example, a theater conventional war with the Soviet Union was not developed as a detailed scenario unfolding in a particular way and occurring in a particular country, but as one of several possibilities developed in sufficient detail to provide some substance on: 1) general conditions in the scenario such as probable location of the activities. (For example, in the near term such a conflict is most likely to occur in Europe, Southwest Asia, or Northeast Asia. In the far term, as the Soviets acquire more projection forces, that will change.);

2) possible political alignments; 3) rates of combat attrition, etc.; 4) the size and type of US, Allied and friendly forces involved (both deployed forces and those that might be mobilized); and, 5) the overall materiel requirements associated with the postulated force levels (what weapons and weapons systems are critical, and in what numbers). These data ultimately translate into estimated production requirements and further, into resulting manufacturing/technology and material requirements that can be examined in terms of foreign dependency and potential vulnerability.

Table 1

National Security Contingencies

1. Peacetime Deterrence
2. Counter-Terrorism
3. Small Conflict: Grenada
4. US Support of Allied Conflict
5. US Involved in Theater Conflict (not Soviet Union): Korea or Vietnam
6. US-USSR Involved in Theater Conventional Conflict
7. US-USSR Involved in Theater Nuclear Conflict
8. US-USSR Involved in Global Conventional Conflict
9. US-USSR Involved in Global Nuclear Conflict
10. War Termination
11. Demobilization and Reconstruction

To assist in reducing the numbers of the systems to be examined and focusing on those of most interest, the framework also requires a set of criteria to assist in both the selection of key systems and the prioritization of weapons and support systems for further analysis for foreign dependencies and potential vulnerabilities.

Selection and Prioritization Criteria

Criteria were developed to assist in the overall prioritization of weapons and support systems that were identified as part of the force requirements in the scenarios. These are shown in Table 2.

Table 2

System Selection Criteria

(a) DEGREE TO WHICH THE SYSTEM IS CONSIDERED CRITICAL TO SUCCESS IN A CONTINGENCY/CONTINGENCIES AND THE IMPORTANCE OF THE CONTINGENCY/CONTINGENCIES FOR WHICH THE SYSTEM IS REQUIRED. Is the system critical in the most important scenario, or key across many contingencies? This criterion provides insight into the relative importance of the system to the overall US national security mission.

(b) PRODUCTION REQUIREMENTS OF THE SYSTEM: NUMBERS, TIME CRITICALITY OF PRODUCTION, AND SOPHISTICATION. A system may be judged critical to performing a mission, but have small wartime production requirements (strategic nuclear weapons, for example, have relatively small surge or mobilization requirements). Further, while peacetime manufacturing dependencies are unlikely to be vulnerabilities, peacetime technology dependencies could be. While this addresses surge and mobilization concerns, it does not address the technology base issue where the focus is on the sophistication of the weapons system and the availability of the technology for the weapons system.

(c) LOCATION AND NUMBER OF SOURCES OF SUPPLY AND LIKELIHOOD OF SUPPLY DISRUPTION. A single source of supply is of particular concern. Sources in some geographical areas are less secure than others. Disruption may occur through either direct attack, SLOC interdiction, political decisions, or general instabilities. The number of sources is important even when these sources are in the United States. Multi-sources abroad might be highly useful for overall survivability and proximity to the conflict in some contingencies.

(d) EFFECT OF THE IDENTIFIED DEPENDENCY ON THE SPECIFIED OR ENVISIONED WEAPONS SYSTEMS OR OTHER ITEMS/TECHNOLOGIES. How, and to what degree, does the dependency slow or preclude the United States from fielding a particular system(s)?

(e) REVERSIBILITY OF THE IDENTIFIED DEPENDENCY. To what degree is it reversible? This ties in with the criticality of time: How soon, and in what quantities, are the weapons systems needed?

Framework Operation

The scenarios and the criteria are used within this framework to: 1) reduce the numbers of systems to be examined for vulnerabilities by forcing an examination of critical US missions, critical systems, and systems production; and 2) evaluate the potential for vulnerability within the remaining systems by examining the potential for disruption and the potential effects of such a disruption. The process is an iterative one, first identifying key systems for further investigation and, after these have been examined for foreign dependencies, determining whether these dependencies are also vulnerabilities. Figure 2 outlines the overall process.

Nature of the Conflicts

While it is not possible to forecast the exact nature of any particular future military operation, it is possible to forecast the general nature and the level of possible military activity in the generic scenarios listed in Table 1. This was done in our analysis and is summarized in Table 3. Peacetime deterrence activities are characterized by operational activities similar to current activities. Contingencies 1 through 4 (Table 1) are characterized by relatively low operational rates, relatively few engaged deployed forces, and relatively low rates of attrition. Contingency 5 (and sometimes Contingency 4) is characterized by moderate levels of deployed US and Allied forces and moderate rates of attrition. Contingencies 6 through 9 are characterized by large numbers of deployed US and Allied forces, high operational levels and high rates of attrition (at least initially). Contingency 10 should be characterized by lower attrition rates, but may retain high operational and deployment rates (a termination through an armed truce, for example) and subsequent demand for high production rates. Contingency 11 implies much reduced rates of military activity, reduced forces, reduced operations, and reduced production rates--subject to a requirement to rearm.

The force requirements for the US in the security contingencies outlined vary in size and complexity from the currently deployed forces considered adequate to fulfill the current peacetime deterrence mission, up to the JCS Planning Force(+). Table 4 briefly outlines these forces. The JCS Planning Force was considered the minimum force required for an initial theater conflict with the Soviet Union--further mobilization would build on that force, and if an extended global conventional war were fought, might include more personnel under arms than in World War II. It would appear likely that a direct theater conflict with the Soviet Union would prompt total mobilization that would be limited only by warning time, duration of the conflict, and level of fighting (conventional versus nuclear). In contingencies with

FIGURE 2

CONCEPTUAL FRAMEWORK

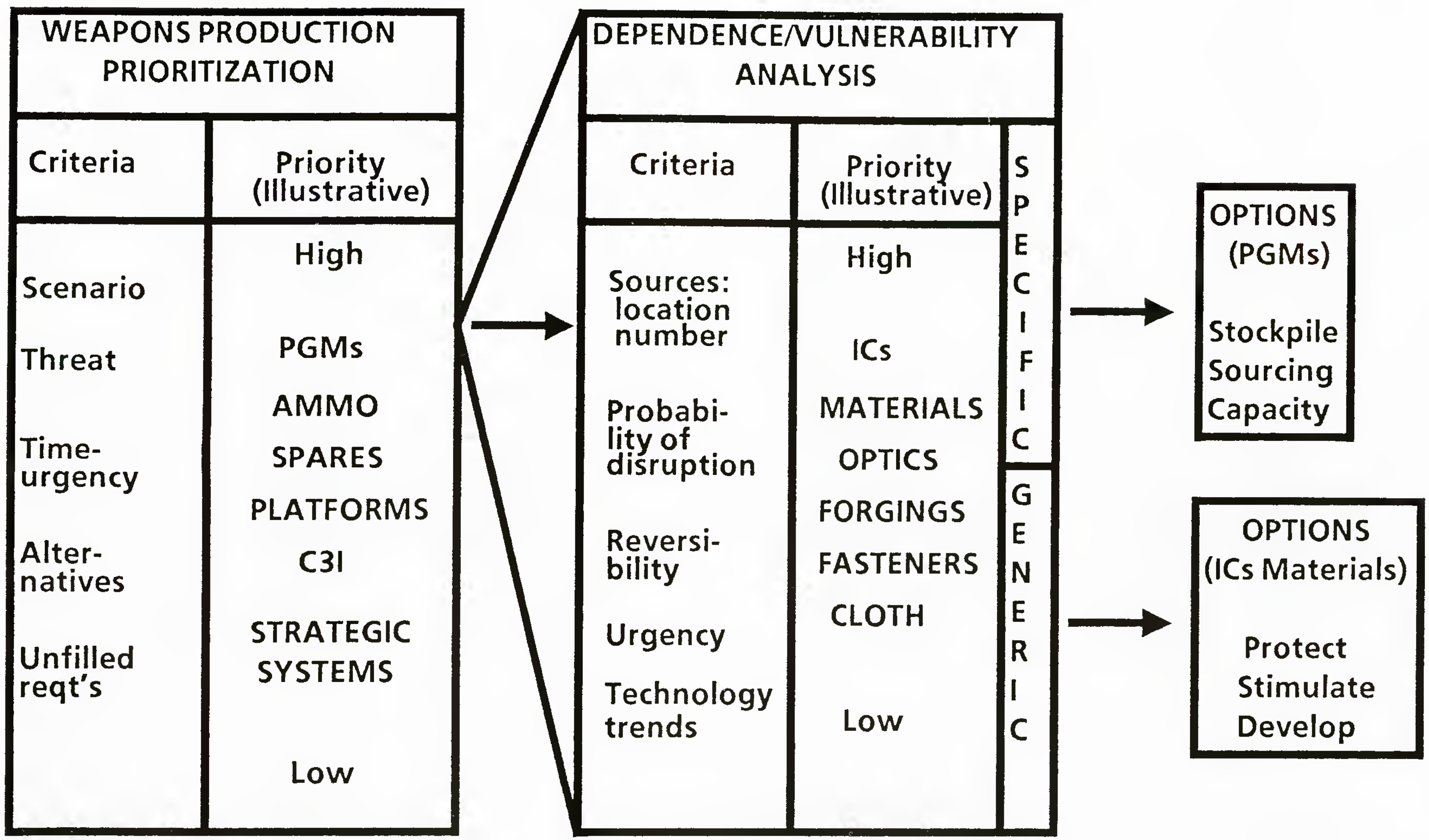

TABLE 3

General Nature and Level of Possible Military Activity

KEY FACTORS / SCENARIO	FORCE PACKAGE	TECHNOLOGICAL/ MATERIAL REQUIREMENTS	MANUFACTURING/ TECHNOLOGICAL DEPENDENCIES	POTENTIAL LOSS OF ACCESS	POTENTIAL VULNERABILITIES
PEACETIME DETERRENCE	All strategic and conventional forces, large, highly complex.	High-tech. (cutting edge). Orderly acquisition, low attrition.	Parts and subcomponents made abroad. Some technologies (GaAS, fiber optics) acquired abroad.	Longterm: tech movement. Nearterm: political, economic, instabilities.	Potential longterm loss of technological edge.
COUNTER-TERRORISM	Small, specialty forces with high-tech weapons.	Small #, complex weapons with high probability of neutralization of a few targets.	Foreign weapons assessed, but manufactured in US. Some overseas parts. All technologies are available.	No loss of access is anticipated, either long or short-term.	No exploitable vulnerabilities anticipated.
SMALL CONFLICT: GRENADA	Ltd. number of peacetime forces with standard, conventional weapons.	Current technology, limited surge production requirements.	Subcomponent dependencies similiar to peacetime. No manufacturing dependencies.	Loss of access is not anticipated, small geographic area involved, low threat.	No exploitable vulnerabilities anticipated.
US SUPPORT OF ALLIED CONFLICT	Transfer of US and Allied conventional weapons, with limited operations support.	Current or past technology and limited-to-medium surge production requirements.	Out of inventory items (obsolete) may require outsourcing.	Potential loss of access connected to level of political support for U.S. activities by source countries.	Not likely, multiple sources, few critical items.
US INVOLVED IN THEATER CONFLICT (NOT U.S.S.R.): KOREA OR VIETNAM	Expansion of US forces up to 50%.	Advanced technology and medium-to-high surge production requirements. Timing and key equipment varies by contingency.	Manufacturing dependencies in high use systems and munitions. Few technology dependencies to meet medium Soviet threat systems.	Potential loss of access connected to level of support for US activities in the conflict by source countries.	More likely than previous case, but still unlikely due to multiple sources, unlikelihood of cut-off of all sources.
US/USSR INVOLVED IN THEATER CONVENTIONAL CONFLICT	Major expansion of US and Allied forces, 2 to 3X. Expansion includes strategic forces.	Advanced technology and high surge rates. High attrition and munitions use rates. Push to develop new improved systems.	Manufacturing dependencies in high use systems and munitions. Potential technology dependencies in defeating top Soviet systems.	Increased potential for loss of manufacturing access due to political decisions or military actions. Loss of technical edge is possible due to political decisions in pre-war period.	Exploitable vulnerabilities depend on theater of operations, (facilities in Europe may be destroyed in NATO war), and technology trends prior to conflict.
US/USSR INVOLVED IN THEATER NUCLEAR CONFLICT	Major expansion of US and Allied forces, 2 to 3X. Expansion includes strategic forces.	Advanced technology and high surge rates. High attrition and munitions use rates. Loss of whole units and major systems possible. Push to develop new and improved systems.	Manufacturing dependencies in high use systems and munitions. Foreign sourcing to make up US shortfalls. Potential technology dependency in defeating Soviet threat.	Loss of manufacturing access likely due to political decisions or military actions. Loss of technical edge is possible due to political decisions and military actions in the war.	Exploitable manufacturing or technological vulnerabilities again depend on theater of operations, but now more likely.
US/USSR INVOLVED IN GLOBAL CONVENTIONAL CONFLICT	Major expansion of US and Allied forces, 2 to 5X. Major strategic force expansion.	Advanced technology and high surge rates. High attrition and munitions use rates. Push to build strategic forces and develop new and improved weapons systems.	Manufacturing dependencies in high use systems and munitions. Foreign sourcing to augment US shortfalls. Potential technology dependency.	Surge items outside the hemisphere subject to cutoff by military actions or political decisions. Technology cutoff possible because of both political and military activities	Single source items are exploitable. Multi-source items are less so.
US/USSR INVOLVED IN GLOBAL NUCLEAR CONFLICT	Total resource mobilization as time allows.	Advanced technology and high surge rates. Once conflict starts whole units, major systems, whole countries subject to rapid destruction. Push to use all available worldwide resources.	Manufacturing dependencies in key weapons systems, degree depends on conflict scenario. Technology dependency depends on trends prior to conflict.	Loss of access possible in all cases.	Single source very exploitable, US as well as abroad. Sources in Europe, NEA are highly vulnerable to cutoff.
WAR TERMINATION	Forces to enforce war termination.	Advanced technology and high surge rates. Production rates depend on nature of conflict and how the war is terminated (truce vs. win). May have rapid build-up or rapid cut-back.	Manufacturing and technological dependencies depend on nature of the conflict, degree of destruction of US base.	Loss of access due to political decisions is possible.	Vulnerability a function of terms of termination.
DEMOBILIZATION AND RECONSTRUCTION	Forces in excess of pre-war levels.	Advanced technology, orderly production rates, levels depend on world tensions.	Same as for war termination.	Loss of access due to political decisions is possible.	Vulnerability a function of terms of termination.

the Soviet Union, an expansion of nuclear, as well as conventional, forces is probable, both as a hedge against Soviet force expansion and to meet requirements for higher alert levels during the conflict.

Table 4

Force Requirements

Peacetime Deterrence	Currently deployed force levels
Terrorism	Ten to 100 personnel in anti-terrorist operation, supported by several thousand transportation, communications, logistics and reinforcing personnel.
Small Conflict	Up to one ground division with limited support, one to three air wings, one to two carrier battle groups and supporting strategic reconnaissance, communicators, transportation and logistics.
Allied Support	Tens to low thousands of US personnel, mostly trainers and logistical support.
US Theater Conflict	Three to six ground divisions with full support, 12-18 tactical air wings and support, recon, and transportation aircraft, two to three carrier battle groups.
US Theater Conflict with the Soviet Union	The JCS Planning Force (+) mobilization of forces continues until war termination.
US Global Conventional and Nuclear Conflict	JCS Planning Force (++....+).

For contingencies between peacetime deterrence and a direct US-USSR conflict, the forces in Tables 3 and 4 are additive to those performing peacetime deterrence, since that mission continues, but potentially with requirements for enhanced strategic and theater forces (depending on the nature of the theater war in which the US might be engaged). These forces vary greatly in size and composition. For example, the Special Operations Forces actually deployed might never number more than a few thousand (tens to hundreds of SOF with supporting conventional forces necessary to feed, transport, and communicate with them during a mission).[10] US forces for support of Allies might also be quite small, depending on the nature of the conflict, but the amount of materiel support provided to the ally might be quite substantial. Forces deployed for small conflicts would not exceed more than one ground division, a carrier battle group (1 to 2 carriers) and 1-2 tactical air squadrons. Finally, forces for a theater war with a country other than the Soviet Union (Contingency 5) could potentially be relatively large (as in Vietnam), and would always probably be ground force heavy, but the exact mix would depend on terrain and Allied involvement. Overall, forces in Contingency 5 could be expected to increase by around 50%.[11] Forces actually deployed in the theater might number 2 to 6 ground divisions, 12 to 18 tactical air and supporting squadrons, and 2 to 3 carrier battle groups.

Future Forces

Unfortunately, those concerned about the effects of foreign dependency have to worry not only about the present, but also, given trends, about the future. What will these future forces look like? In what Herman Kahn once termed a "surprise free future," the types of forces deployed over the next twenty-five years will probably be evolutionary--i.e., we will still have tanks, aircraft carriers and many of the major weapons platforms that currently exist by virtue of the fact that short of a major conflict we have sunk costs that preclude total inventory change. This situation could change as a result of: 1) some radical new weapons development such as deployment of new directed energy weapons (although nuclear weapons did not do away with the previous force structure), or 2) a major war (we did get rid of the horse cavalry in WWII). However, it is more likely that many current forces will be retained, with some additions that make

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10. The raid on the Son Tay prisoner camp, for example, had a raiding force of fewer than 100 men armed with small arms, three C-130, and five H-53 helicopters, supported by aircraft from three aircraft carriers, land based aircraft in the attack area, and C3 and medical aircraft plus command and control that went back to the Pentagon. Benjamin F. Schemmer, The Raid, Harper and Row, 1976.

11. In the three years between 1965 and 1968, U.S. forces increased by more than 45%; the Army 63%, the Marines 61%, the Air Force 44%, the Navy 17%. This was in addition to a buildup that had begun in 1961. John M. Collins, Defense Trends in the United States 1952-1973, Congressional Research Service, 1974 and John M. Collins, The United States/Soviet Military Balance: A Frame of Reference for Congress, Senate Armed Services Committee Print, 1976.

them more effective--better sensors, more effective killing mechanisms, et cetera. The forces that might be deployed in the future could potentially be smaller, more mobile, and have killing power at greater distances. The peacetime deterrent forces will probably include more strategic defense forces. All will have more space components. The technologies that currently appear likely to have the greatest potential to make those changes occur are in highly competitive areas of high technology such as electronics, new materials, and high energy physics.

Materiel Requirements

The consideration of contingency force requirements provides insight into the type of materiel requirements associated with the individual generic scenarios (for example, the most advanced systems required to face the Soviets; potentially obsolescent systems to arm Third World allies fighting insurgencies) and the overall quantitative requirements for this materiel. A US-Soviet conflict could be expected to be a high intensity, high attrition conflict while a US theater war with another opponent might have relatively low rates of attrition. As we have seen in the Falklands War and the recent US losses in the Persian Gulf region, however, there might be losses of major platforms to advanced weapons in any conflict. The assessments of which weapons and support systems are critical and should be examined further are subjective and are highly dependent on estimates about the likelihood of a particular conflict occurring and how that conflict would be fought. Materiel requirements will therefore change somewhat from estimate to estimate. Some analysts will give more weight to one system over another. However, in the near term the range of requirements is constrained by the weapons systems in the inventory. In the far term, new weapons and supporting systems are developed, with new missions, new kill probabilities, and new overall mixes on the battlefield. Whether near or far-term, the systems should be prioritized according to their perceived criticality to accomplishing US objectives.

Sources to further define materiel requirements include: evaluation by service planners, examination of prioritized service lists, and war games. There are problems with using any of these sources to determine which systems are important and how important they are. The prioritized lists, for example, may have more to do with peacetime procurement battles than with wartime operations. Further, they generally exclude items such as spares and repair parts. However, they can be used, along with the other sources, to assist in development of priorities on key systems for further examination for foreign dependency and foreign vulnerability.

Using the scenarios in Table 1, the criteria in Table 2, our assessment of missions, and information from sources noted above, we then developed a representative materiel requirements list in Table 5.

In applying criterion (a) from Table 2, consideration was given to the fact that deterrence of nuclear war remains the most important US mission and thus strategic nuclear weapons and supporting systems remain the most important class of weapons systems in the US arsenal. This is true both for peacetime deterrence and across the conflict spectrum since such weapons are believed essential to ensuring against nuclear blackmail or nuclear attack on the United States or its allies.

The next most important are theater nuclear weapons and high technology conventional weapons systems that are perceived to have great leverage against Soviet offensive systems (for example, advanced fighters and fighter/bombers, combined with conventionally armed precision guided munitions to destroy Soviet aircraft and slow or stop Soviet armored columns, as well as naval platforms armed with these systems and ground platforms armed with such systems). All these systems are designed to blunt a Soviet/Warsaw Pact attack into Europe or Southwest Asia. Also included in this category are communications and surveillance and command and control essential to making such high technology systems operate effectively.

The next level down from these potentially "high-payoff" weapons are level-of-effort munitions essential to fighting a conventional conflict, and in the case of a conflict with the Soviet Union, essential to insuring against a requirement for NATO escalation to nuclear weapons to stave-off conventional defeat. These items include conventional artillery rounds, "iron" bombs, sonobouys and depth charges that are needed in volume to successfully fight a conventional war.

Not shown in Table 5, but further down a prioritized list of required systems are such items as individual and crew served weapons, and special operations equipment: items that are critical for accomplishing certain key tasks, but not critical to national survival. However, for understanding the effects of a potential disruption, determining which systems are militarily important is only one discriminator. A second key factor to consider is production requirements.

Production Requirements

Rapid, uninterrupted production is essential in both surge and mobilization. In further narrowing the systems to be examined, a fundamental requirement is determining the differences between the projected requirements for a particular system in

TABLE 5
MATERIEL REQUIREMENTS

SPACECRAFT

DSP
DSCS III
CPS

Missiles

MX
MMIII
PERSHING II
PATRIOT
TRIDENT C4/D5
ATLAS
SHUTTLE
TITAN/CELV
CENTAUR
TRANSTAGE
INERTAL UPPER STAGE (IUS)
DELTA
AIM-54C
AIM-7M (SPARROW)
AIM-9 (SIDEWINDER)
AGM-88A
RIM-67A ST ER
RIM-66A ST MR
BGM-71 TOW
AG-114A
RGM-84
UGM-84
FIM-92A
IMPROVED-HAWK
AGM-65D A/B/C/D
BGM-109 TOMAHAWK GL/SL
ARM-AGM 78
ALCM/AGM-86B
AGM-69A/SRAM II
GLCM

AIRCRAFT

B-1
B-52
F-15
F-16
F-18A/C/D
F-14A/D
F-111
AV-8
E-2
E-4
E-6
E-3
KC-135
EC-130G/Q
P-3
C-5A
MC-130
AH64

VEHICLES

M1 TANKS
M2/3 FIGHTING VEH
M-109 HOWITZER
M-110 HOWITZER
CARGO TK 5TON
HMMWV

C^3I

JTIDS
SINGARS

MUNITIONS

MINE MK-60
TORPEDO MK-48
GBU-89 GATOR MINE
GBU-15
CTG 105MM APFSDS-T
PROJ 8" HERAP
MK-84 BOMB
PROJ 155MM ADAM
PROJ 155MM M483
PROJ 155MM M712
PROJ 120MM M865
M-46 TORPEDO

OTHER

SONOBOUYS
CHAFF

a scenario of interest and the stocks on hand (Criterion (b) Table 2). In the case of strategic nuclear systems, additional surge or mobilization requirements are relatively low, perhaps tens to hundreds. For key theater conflict items such as precision guided munitions, however, the additional projected wartime mobilization requirements number in the tens to hundreds of thousands. For level-of-effort munitions, such as 155mm artillery rounds, requirements number in the millions. A surge or mobilization foreign dependency in one of these areas is a potentially far more serious problem than in a system requiring little additional production.

We did not include major naval vessels in the consideration since their estimated production times in many cases are so long that foreign dependency (other than raw materials) would probably not have a major impact. However, components of naval vessels (radars, engines, communications weapons systems) were considered as they relate to keeping currently deployed vessels in the war. Consideration of production resulted in priorities shown in Table 6.

TABLE 6

Priorities

Surge and Mobilization	Technology Base
Precision Guided Munitions	Strategic Nuclear Forces
Level-of-Effort Munitions	Theater Nuclear Forces
Spares and Repair Parts	Precision Guided Munitions
Medical Support Items	Theater Aviation Platforms
Theater Aviation Platforms	C3 Systems
Ground Combat Systems	Chemical Systems
C3 Systems	Level-of-Effort Munitions
Theater Nuclear Forces	Ground Combat Systems
Strategic Nuclear Forces	Medical Support Items
Clothing and Tentage	Clothing and Tentage
Construction Materials	Construction Materials

The production requirements and the concerns over the potential for technology base vulnerability are different from those of surge and mobilization. As we noted earlier, the concern in technology base vulnerability is not time dependent, but focused on the inability to retain sufficient access to advanced technology to maintain a technological edge over our enemies, to avoid a reduction in weapons effectiveness and, ultimately, to change the overall military balance between the US and the Soviet Union. This is a potential problem for all high technology forces regardless of surge or mobilization numerical requirements. While the priorities in the systems differ somewhat for technology base from surge and mobilization, as shown in Table 6, there are some broad system areas that remain relatively the same. Given current ideas about how conflicts will be fought, precision guided munitions are high in all three areas of concern. Spares and repair parts, particularly in avionics and radars, are also high on all lists.

Far-term Materiel and Production Requirements

In the far term one would estimate that weapons are going to be more discriminating, with higher single-shot kill probabilities. Materiel requirements (numbers) might be lower, and assuming some reasonable stockage rates, so might production requirements (although individual costs would have an impact on stockage). However, it is difficult to estimate far term requirements, and it is probably of more use to concentrate on technologies with potential impact on military systems including:

- Microelectronics
- Materials
- Directed Energy
- Telecommunications
- Optics (including electro-optics and fiber optics)
- Biotechnology

While the overriding concern during surge and mobilization is on meeting production schedules for systems, in the far-term the concern is on insuring against technological surprise while fielding the most effective military systems. Because we cannot predict surprise (nor unknown scientific developments and their impact on the military) the United States needs access to a broad range of technologies. That access might come through maintaining access to foreign technology bases, however, this is more difficult in the technology area than in manufacturing.

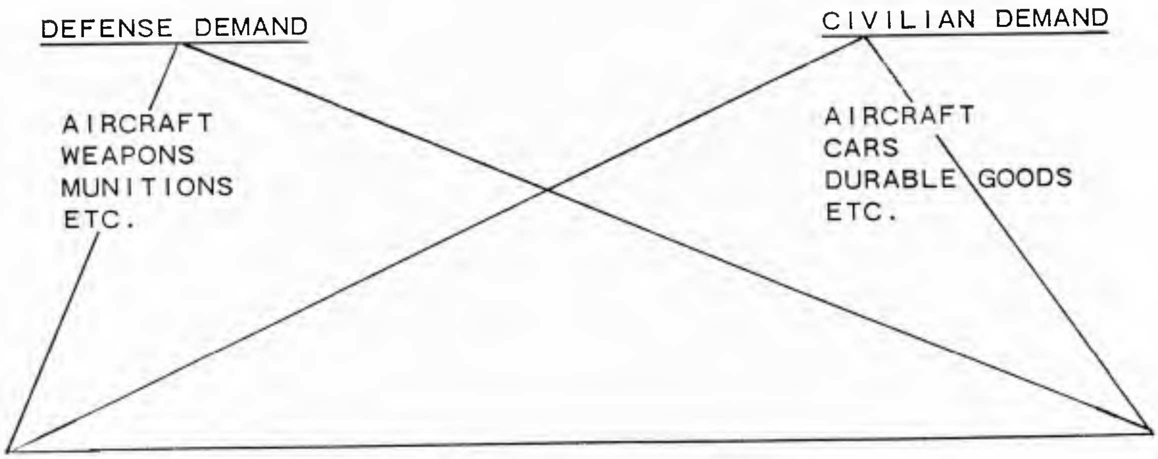
Determining Potential for Vulnerability

Once the analysis framework has reduced the problem to a more manageable group of selected systems, they can be examined in detail for potential foreign dependency and vulnerability. This step must address each type of potential vulnerability --surge, mobilization, and technology base. A single system might have foreign dependencies in all three areas, or several systems might share the same dependencies: key sub-components, manufacturing tools or procedures, etc.

Figure 3 illustrates the interrelationship between the civilian and the defense bases. The investigation of individual systems leads to identification of industrial sectors for further investigation. For example, many of the studies examined in the

Figure 3

PRODUCTION RELATIONSHIPS



END PRODUCT	–	AEROSPACE, ELECTRONICS (E.G. COMPUTERS, TELECOMMUNICATIONS, SOFTWARE), SHIPBUILDING, AUTOMOTIVE, CONSTRUCTION EQUIPMENT, FARM MACHINERY, ETC.
SUBTIER	–	FORGINGS, CASTINGS, BALL BEARINGS, MACHINE TOOLS, ROBOTICS, SEMICONDUCTORS, SEMICONDUCTOR EQUIPMENT, ETC.
BASIC	–	STEEL, PETROCHEMICALS, METALS, (E.G. ALUMINUM, TITANIUM, COPPER, MINING), CERAMICS, COMPOSITE FIBERS, OPTICS, ETC.
INPUTS	–	RAW MATERIAL, ENERGY, CAPITAL, TECHNOLOGY, SCIENTIFIC/SKILLED MANPOWER, MANAGEMENT.

Source: Roderick Vawter, US Industrial Base Dependence/Vulnerability: Phase I - Survey of Literature, MCDC, December, 1986, p. 62.

literature review identified microelectronics, specifically integrated circuits, as a key sector for investigation. Some other indicated new materials. The discovery of foreign sourced components, common to a number of weapons systems, might provide an opportunity to concentrate on eliminating "generic" vulnerabilities that might exist (either in sub-components--microelectronics, or in manufacturing requirements--machine tools), rather than concentrating on eliminating the specific identified vulnerabilities in a system-by-system manner.

To be effective, a system examination must be conducted on at least three levels. The first level is the end item level. Do we buy the entire end item from abroad? Level two is the purchase of sub-components--such embedded items as integrated circuits, etc. This is much more common and the cause of many concerns, particularly related to surge. Level three is an examination of the mobilization production requirements for the system to develop an understanding of whether what are currently considered internal mobilization constraints, might in reality be foreign dependency related (and on the positive side, where these constraints might be removed by planning for foreign sourcing).

Missile X

For example, Missile X, an Army anti-tank weapon, might have the following general production requirements:

Peacetime	Surge	Mobilization
X,000/month	(1.5)X,000/month	(8)X,000/month

During peacetime, the US is initially concerned over whether Missile X can defeat Soviet armor. As the system is developed, the United States asks such questions as: does the missile have the capability to destroy Soviet armor and does it have effective sensors and guidance? These are potential technology base issues. These technology base questions do not end when the weapon is fielded since there can be weapons modifications later. However, once the weapon is fielded and there is some production rate established, the main concern shifts to potential surge and mobilization issues. The concentration on potential surge vulnerabilities is probably at the sub-component level since the surge requirement may not require physical plant expansion. At the mobilization level, however, meeting projected production levels probably requires plant expansion, new machine tools, increased forgings and castings, etc. -- far beyond current capabilities. The extent to which these have possible foreign dependencies is related to current alternative capabilities within the US that are applied to non-defense work, but can be shifted to defense work. How rapidly this shift can occur (Criterion (e)) is important.

With Missile X's surge and mobilization problems understood, those concerned about the follow-on to Missile X (Missile X1) have to be concerned about the trends in the technology base. Will the country have sufficient access to technology to make Missile X1 superior to the future threat?

Potential For Disruption

Even after determining the importance of a system or component, identifying clear foreign dependencies and examining their reversibility, there is still not necessarily a clear vulnerability. As we noted in Figure 1, foreign dependence is a necessary, but not sufficient condition for vulnerability. In all three types of potential vulnerability (surge, mobilization, and technology base) there must be a disruption. There is potential for disruption of supply in all eleven contingencies outlined in Table 1. Such disruptions are a function of military action, political decisions, general instabilities (labor strife or local revolution for example), and natural disaster. Figures 4, 5, 6 and 7 summarize relative probabilities of sources of disruption from a particular geographic source of supply during selected security contingencies and illustrate a way to think about the potential for disruption.

The US draws materials and services from a number of sites, each having some probability of disruption. In the contingencies ranging from normal peacetime deterrence through theater conflict (1-5 in Table 1), the probability of an extended supply disruption is considered relatively low (Figure 4). However, even so, there are reasons for some concern. The Arab oil embargo, while not actually reducing US petroleum stocks, was costly and affected US and Allied national security policy. It, and the earlier Soviet embargo of manganese and chromium in 1949, are both examples of political decisions by foreign governments that can affect US security.[12] Strikes in the Canadian nickel mines in 1969 are also cited as having caused some national security concerns as well as "actual shortages and acute price hikes. Yet military and essential civilian production were never interrupted in the United States."[13] The more recent destruction of a new tantalum facility in Thailand has been variously attributed to either a general riot or a directed terrorist act. Low level conflict in Africa has several times threatened US sources of

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[12] Lionel S. Johnson, et. al., Strategic Materials: Technologies to Reduce U.S. Import Vulnerability, Office of Technology Assessment, Washington, D.C., GPO, 1985, p. 91.

[13] Ibid., p. 94.

strategic minerals. The probability of a natural disaster is about equally distributed.

Clearly, Southwest Asia, Africa and Latin America hold the most potential for disruption due to general unrest and war. These are principally sources of raw materials rather than manufactured goods.

Military disruption of a significant nature is possible in scenarios 5-7 (Theater War with the Soviet Union to Global Nuclear Conflict), and is highly likely in scenarios 8 and 9 (Global Conventional Conflict and Global Nuclear Conflict). The exact nature of any disruption is highly scenario and geographically dependent.

In the near term, a theater conventional conflict between the United States and the Soviet Union would probably be confined to one of four geographical areas (Figure 5). The probability of a disruption caused by military action would be high in the theater where combat was occurring. Thus, in a European conflict, disruption might occur from either direct action against manufacturing facilities or attacks on the lines of communications. By definition, military disruption would not occur in other theaters; however, disruption due to political decisions might. For example, oil suppliers in the Persian Gulf might, because of direct pressure from the Soviet Union, decide to stop shipment to NATO during a conflict in Europe. While the threat of direct Soviet action might be relatively high in Southwest Asia (SWA) and Northeast Asia (NEA), it is less likely in Africa, Latin America, and Southeast Asia and the possibility for political coercion is thus lower. Similar reasoning affected the other estimates.

Figure 6 reflects the assessment that non-engaged countries might be much more easily coerced with nuclear weapons, and a political cutoff is therefore more likely. Further, the military destruction in-theater is higher.

These same distinctions between a nuclear and non-nuclear conflict are evident in a global conflict (Figure 7). The threat of a military disruption from this combination appears high in Europe and Northeast Asia in both a non-nuclear and a nuclear conflict. It is a lesser threat in other geographical areas. However, the disruption probability is high in areas that have traditionally been viewed as most likely to have goods of particular interest: the manufacturing areas of Europe and Northeast Asia, and the petroleum producing regions of SWA and the Persian Gulf.

FIGURE 4

PROBABILITY OF DISRUPTION
PEACETIME DETERRENCE - U.S. THEATER CONFICT
OTHER THAN USSR

CAUSE OF DISRUPTION	EUROPE	SWA	AFRICA	LA	NEA	SE ASIA	CHINA	SOVIET BLOC
GOVERNMENT DECISION	L	L-M	L-M	L	L	L	L	M
STRIKES/CIVIL STRIFE	L	L-M	M	M	L	L	L	L
TERRORISM	L-M	M	L	M	L	L-M	L-M	L
LOCAL WAR	L	M	M	M	L	L	L	L
NATURAL DISASTER	L	L	L	L	L-M	L-M	L-M	L

L - LOW PROBABILITY
M - MEDIUM PROBAILITY OF DISRUPTION
H - HIGH PROBABILITY OF DISRUPTION

SWA - SOUTHWEST ASIA
NEA - NORTHEAST ASIA
LA - LATIN AMERICA

FIGURE 5

PROBABILITY OF DISRUPTION
THEATER CONVENTIONAL CONFLICT US/USSR

AREA OF CONFLICT

LOCATION OF SOURCE	EUROPE (P)/(M)	SWA (P)/(M)	NEA (P)/(M)	WAR AT SEA (P)/(M)
EUROPE	L/H	L/NA	L/NA	M/H
SWA	M/NA	L/H	L/NA	M/H
NEA	M/NA	M/NA	L/H	L/H
AFRICA	L/NA	M/M	L/NA	M/L
LA	L/NA	L/NA	L/NA	L/L
SE ASIA	L/NA	L/NA	L/NA	L/M

(P) - POLITICAL ACTION
(M) - MILITARY ACTION
L - LOW PROBABILITY OF DISRUPTION
M - MEDIUM PROBABILITY OF DISRUPTION
H - HIGH PROBABILITY OF DISRUPTION
NA - NOT APPLICABLE

SWA - SOUTHWEST ASIA
NEA - NORTHEAST ASIA
LA - LATIN AMERICA

FIGURE 6

PROBABILITY OF DISRUPTION
THEATER NUCLEAR CONFLICT US/USSR
<u>AREA OF CONFLICT</u>

LOCATION OF SOURCE	EUROPE (P)/(M)	SWA (P)/(M)	NEA (P)/(M)	WAR AT SEA (P)/(M)
EUROPE	M/H	M/M	M/NA	H/H
SWA	M/NA	H/H	M/NA	H/H
NEA	M/NA	M/NA	L/H	M/H
AFRICA	M/NA	M/M	L/NA	H/H
LA	L/NA	L/NA	L/NA	L/M
SE ASIA	L/NA	M/NA	M/NA	M/H

(P) - POLITICAL ACTION
(M) - MILITARY ACTION
L - LOW PROBABILITY OF DISRUPTION
M - MEDIUM PROBABILITY OF DISRUPTION
H - HIGH PROBABILITY OF DISRUPTION
NA - NOT APPLICABLE

SWA - SOUTHWEST ASIA
NEA - NORTHEAST ASIA
LA - LATIN AMERICA

FIGURE 7

PROBABILITY OF DISRUPTION
GLOBAL CONFLICT US/USSR
LOCATION OF SUPPLY SOURCE

NATURE OF THE DISRUPTION

		EUROPE	SWA	NE ASIA	AFRICA	LA	SE ASIA
NON-NUCLEAR	MILITARY	H	M	H	L	L	L
	POLITICAL	L	M	L	L	L	L
NUCLEAR	MILITARY	H	H	H	L	L	M
	POLITICAL	M	H	M	M	M	H

L - LOW PROBABILITY OF DISRUPTION
M - MEDIUM PROBABILITY OF DISRUPTION
H - HIGH PROBABILITY OF DISRUPTION

SWA - SOUTHWEST ASIA
NEA - NORTHEAST ASIA
LA - LATIN AMERICA

The Threat of Technology Cutoff

The previous discussion focused on threats to production related to either surge or mobilization vulnerability. Concern over the technology base is a special case currently largely focused on Japan, and the developments occurring in such areas as micro-electronics, computers, optics and electro-optics, and new materials that might have application in new high technology weapons systems, especially in guidance, sensing, and data storage. The concern is over the degree to which the US may lose its technological edge and, having become dependent on Japan for the advanced technology, not have ready access to that technology, thus potentially shifting the balance of deterrence and the outcome of a possible war with the Soviets.

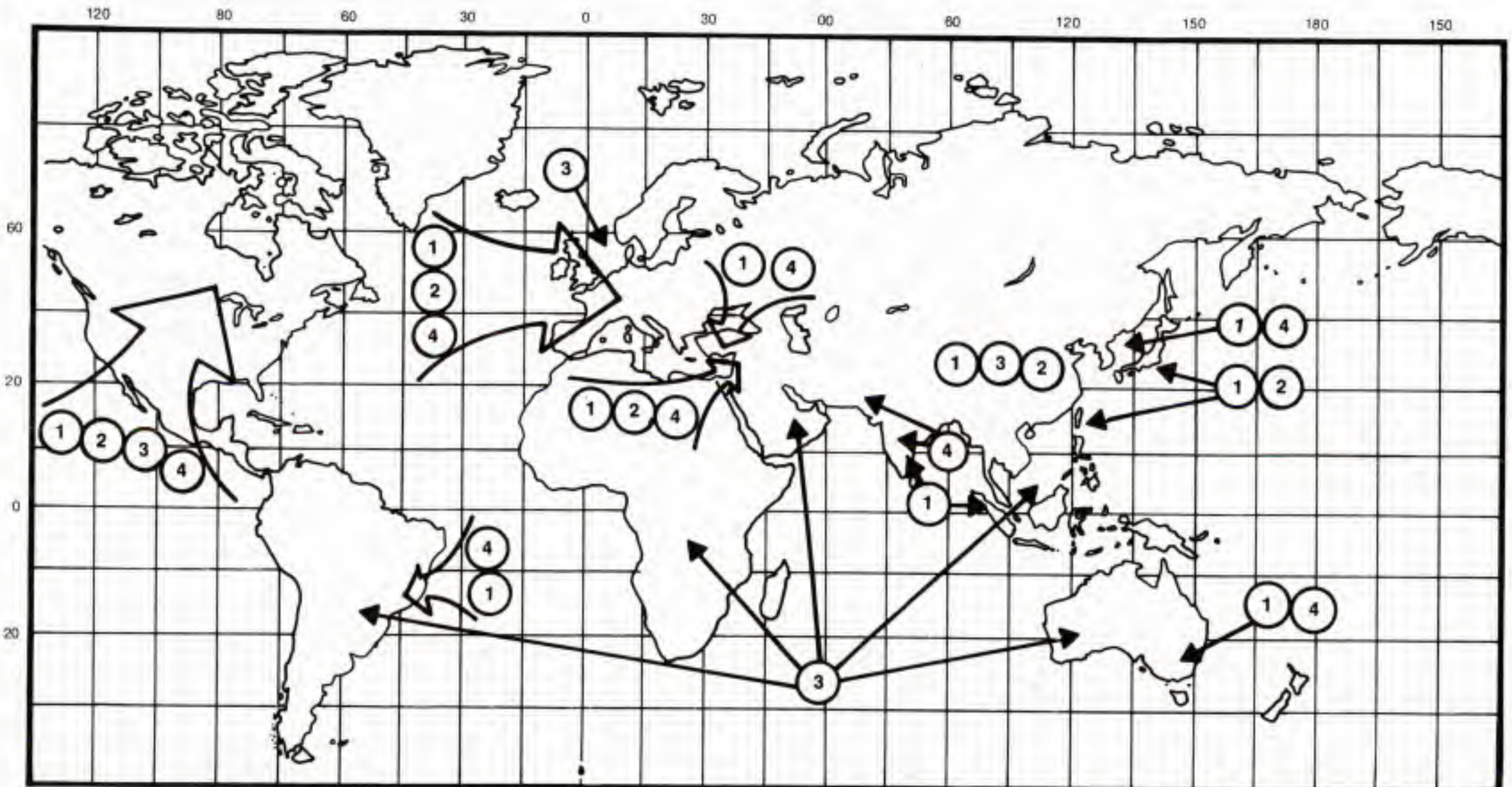
The potential for such a cutoff is unclear. The possibility exists, but it must be considered within the context of the relations between the US and its allies. Access to technology from allies is an asset as well as a potential problem. It is a bigger pool of technology, with more ideas available, allowing the US and its allies to maintain an even greater edge over the Soviets. Prior to World War II the US acquired much useful technology from abroad that made major contributions to that war effort. There is no clear evidence that the United States will not continue to have access to foreign technology, however that access might not be as rapid as desired.

General Sources of Supply

The number and location of sources of supply determine the potential for disruption. Thus if there are many widely spaced sources, the probability of disruption, under many circumstances, might be small. Figure 8 shows the general dispersal of manufacturing, technology, and raw materials outside the Soviet bloc.

Despite a relative loss of manufacturing capacity and preeminence in high technology, the United States--actually North America in general--remains an important source of manufacturing, high technology, raw materials and production of military systems--the major source for most. The world has changed, however, in the past 40 years. High technology centers now also exist in Japan and Europe, with smaller centers in Israel, India, China and Taiwan. Manufacturing is even more widespread, although defense manufacturing is less so. In addition to North America, Europe produces both high technology systems (missiles and high performance aircraft) and volume conventional arms (Spain and Turkey). Brazil has a very active defense industry, as does India and Korea. Singapore, Australia, and Taiwan all have small, but advanced, capabilities. Japan lags in this area but has the potential to modify its civilian industry for production of military goods.

Figure 8
Supply Sources Outside Soviet Bloc



1 Manufacturing Center

2 High Technology Center

3 Raw Materials

4 Military Systems Manufacturing

Raw materials come from throughout the Third World with key deposits in the Persian Gulf, South Africa, Southeast Asia (oil and minerals), China (oil and minerals), Australia (minerals), South America (minerals) and the Caribbean (oil).

In addition to changes in point of production, the world has changed in other ways that affect access to key products. Many of the products are more easily transported and more readily sourced than in the past. (ICs are an example.) These changes reduce the effectiveness of potential disruptions.

Disruption Effectiveness

A final consideration is that the effectiveness of any particular disruption is a function of both its duration and its thoroughness. These are, in turn a function of the opponent's capability to enforce the disruption and our own ability to overcome it, either through reopening the source (rebuilding the plant or ensuring the safety of the LOC) or reconstitution. Figure 9 illustrates some of the relationships to consider. A political cutoff might be of long duration, but might be porous (the Arab oil embargo). LOC interdiction might be thorough, but rapidly overcome by counter action. However, a cutoff due to direct military action (destruction or capture of a manufacturing facility) might be both thorough and of long duration, especially if the items cannot be easily reconstituted. The risks associated with single source, potentially vulnerable factories and supply sites, particularly those near Soviet bloc territory, are obviously high.

It is more difficult to enforce a disruption today than in the past. There are many more potential sources of supply, there are other means to move products (air versus sea), and factories and personnel in key industries (electronics) are potentially more mobile. In the changed conditions, the key to assured supply might be less on ensuring the supply exists in the United States than on ensuring that it exists several places world-wide (including the US) where the US has good relations.

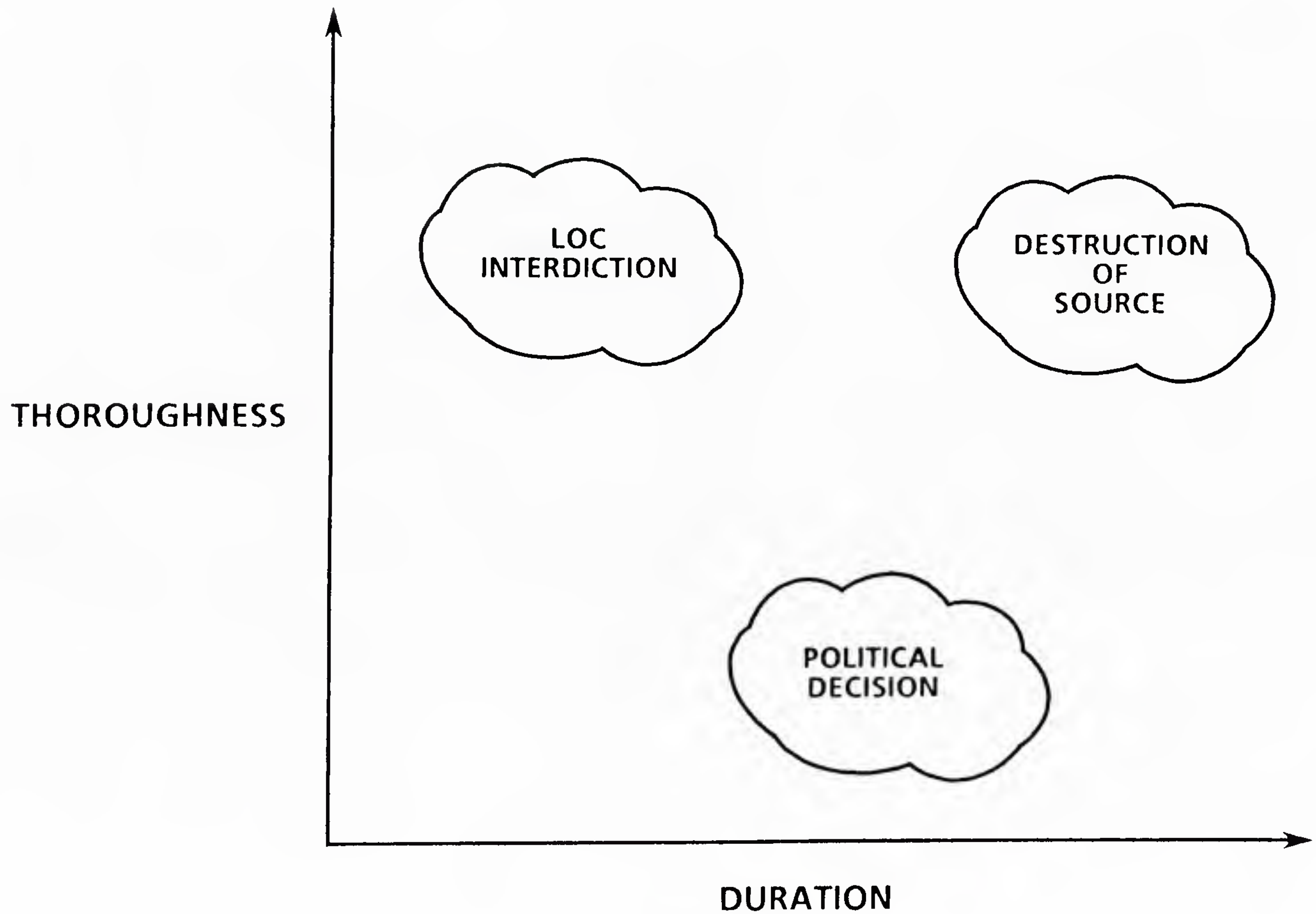
Summary

The framework that has been outlined in this section provides a means to: 1) prioritize where study effort should be placed, and 2) evaluate the potential for vulnerability that exists in systems selected for further study. It depends on subjective judgments about such things as probabilities of conflict and probabilities of disruption (issues which decision makers must confront if they are going to adequately deal with foreign vulnerability), but makes these issues explicit so that they can be discussed and considered. The case studies in

Sections Three, Four, and Five are directed at items considered key by many in the national security community. The case studies further illustrate the process.

Figure 9

DISRUPTION EFFECTIVENESS



SECTION THREE

The Impact of Foreign Source Dependence on Weapons Parts: A Case Study of the Precision Guided Munitions (PGM) Sector

Using foreign sources in weapons production can offer many benefits, from lower costs and better technology to increased competition and better Allied integration. Such use carries risks, however. If critical parts from abroad are suddenly unavailable, weapons production stops until domestic sources can be found to replace parts previously purchased overseas. The length and severity of disruption varies with several factors: the criticality of the part, the percentage of such parts purchased domestically, the production lead time of the part, and, in particular, the presence of a qualified domestic producer. Because these factors differ widely among affected components, nothing less than a case-by-case examination of weapons at risk will suffice to indicate the extent of the risk and the cost of managing it.

This section examines precision guided missiles (PGMs) as a class at risk from an unanticipated foreign source cutoff. This class was chosen for two reasons. First, the Commanders-in-Chief have repeatedly indicated that they need PGMs first in any production ramp-up. Second, prior JCS and Navy studies have created a large data base on the industry.

Table 7

PGMs Examined in this Study

PGM	Platform	Target	Seeker	Users
Sidewinder	Air	Air	IR	N/MC, AF
Sparrow	Air	Air	Radar	N/MC, AF
Phoenix	Air	Air	Radar	N
HARM	Air	SAM sites	Radar	N/MC, AF
Harpoon	Air/Sea/Sub	Ship	Planar Radar	N, AF
Tomahawk (C)	Sea/Sub	Ship/Ground	Planar Radar	N
Standard	Sea	Air	Radar	N
MK 46 Torpedo	Air/Sea	Submarine	Sonar	N
GBU-15	Air	Ground	TV	AF
IR Maverick	Air	Ground	IR	AF, N/MC
Laser Maverick	Air	Ground	Laser	N/MC
Skipper	Air	Ship/Ground	Laser	N/MC
Copperhead	Artillery	Armor	Laser	A, MC
TOW	Ground	Armor	Optical	A, MC
Hellfire	Helicopter	Armor	Laser	A, MC
Patriot	Ground	Air	Radar	A
Stinger	Ground	Air	IR	A, N/MC, AF

The PGM industry is a six billion dollar industry as measured by the cost of purchased hardware in the FY 86 budget (including foreign military sales). Table 7 lists the PGMs studied.

The Surge Context: Disruption as a risk has to be evaluated in the context of a wartime surge. Almost all of the affected components come from friendly countries. They are unlikely to withhold components during peacetime; more likely, only war would prevent our access. A cutoff would likely occur just as production would have to be accelerated. Both the cutoff and the associated conflict would lend urgency to accelerating both manufacturing and the search for substitute domestic components. As such, the disruptions from a cutoff of specific components may be associated almost exclusively with surge. The importance of such subcomponents to maintaining, much less expanding, production would contrast with the heightened urgency that accelerating production would have over the interval.

There are few, if any, parts from overseas which cannot be replaced by domestic production within a year or two. Given the US strategy of forward defense, however, any early weapons shortfalls would take place during a particularly critical period.

Bear in mind that references to a cutoff assume that such actions are unanticipated. If industry knew it would have a year's warning, it could purchase additional supplies during that period. Thus, it would not have to depend on any prior preparations to ride out the crisis. An unanticipated cutoff, of course, affords no such opportunity and must be insured against beforehand.

Methodology: Should foreign-sourced components become unavailable, the production of weapons which use them will be cut. As JLC Study argues, deliveries will cease for up to a year, roughly the time required until domestic sources can produce all parts previously made overseas. Most of the production otherwise expected in the first year of a crisis, however, would be lost.

This establishes the basic questions. What is the extent, nature, reason, and length of this disruption? What can be done to prevent it beforehand, and how much will this cost?

To answer these questions requires first knowing the extent of foreign sourcing in the PGM industry. Where foreign sourcing has been determined, does this sourcing create a dependency? As defined in Section 2, the two are not the same. Companies may choose to buy parts overseas which they can as easily (if not as cheaply) buy here. In a crisis, if domestic capacity is sufficient, companies can return to domestic sources. For other components, however, there is either no qualified source, no domestic source with enough capacity, or a substantial production lead time that would inhibit the prompt replacement of overseas supply. These latter components are the ones of interest.

Assuming the existence of such components, the next question is "What it would take to buffer the production schedules against the risks of a cutoff?" What kind of insurance would the industrial base need to minimize its exposure to overseas events? Policies to protect production schedules are many and varied. Among them are eliminating the foreign sourcing to begin with, creating the stand-by capability to pick up production in emergencies, and creating a buffer stock of components large enough to bridge the gap between a cutoff and a domestic production recovery.

It is the last method--creating a buffer stock--which this paper uses as an estimate of the upper bound of the cost of insuring production schedules. Buffer stocks have the advantage that they can be applied to any foreign source dependence at the subcomponent level, and the solution is straightforward to implement. Buying inventory (more specifically, requiring its purchase; see below) is the least costly alternative, partially because such stocks can frequently be reabsorbed into final-year production contracts for dependencies which are specific to individual weapons programs. In many cases, particularly where dollar values are small, it would be cheaper to buy the inventory than it would be to commission a study on the problem. In some cases, such as rocket motor cases, buying standby capacity is cheaper than buying the inventory required to support downstream production until capacity is adequate.

Finally, other alternatives can be evaluated in a straightforward way by calculating how much they reduce the requirement to hold buffer stocks by either eliminating the dependence or shortening the domestic recovery time.

Buffer stocks work as follows. Normally, a domestic producer gets shipments from overseas. If an unexpected cutoff takes place, such shipments would stop. The factory would then begin to draw components, no longer from shipments, but from a stock of component inventories especially created and sized for this emergency. At the same time, domestic manufacturers would be asked to produce the affected components as quickly as possible. After a period, which would vary with each item, domestic producers would begin shipping such components to compensate for lost overseas shipments. If the buffer stock is correctly sized, the PGM factory would just have exhausted the buffer stocks when the domestic supplier came on line.

Calculating the correct size of the buffer stock requires knowing only two things. One is how many components are expected from overseas every month. If a foreign source is only shipping a fraction of the total component buy, then the buffer stock is sized according to what percentage of the components are bought abroad. The other is how many months it would take for a domestic source to ship at rates previously supplied from overseas. This time would be short if the product is simple and/or the most likely domestic sources are technologically capable of producing the item. The time would be long if domestic firms have to be qualified to sufficiently high quality-control standards.

If the time required to replace a foreign source extends to a half a year, then additional inventory may be required to support, not only current production rates, but higher rates characteristic of production surge. The latter rates measure what it would take to keep the dependency from hobbling acceleration schedules under crisis conditions. Throughout this study, we have assumed that the domestic substitution of hitherto foreign sourced items would take place under wartime conditions, i.e., as quickly as possible without regard to costs. Thus, substitution times may be faster than what would otherwise occur under business-as-usual conditions.

(This study does not price the stockage costs for materials which are, or should be, in the National Defense Stockpile as it would double-count the results of the minerals-and-materials case study in the next section.)

Tasks

The basic tasks of this section are to unearth as many instances of foreign subcomponents in PGMs as possible, determine which instances represented dependencies, and estimate the cost of stocks required to buffer both existing and surge schedules.

Instances of foreign subcomponents were provided from many sources. The main one was the second phase of the JCS study of PGMs.[14] For that study, 500 companies identified as suppliers of at least one major part to a PGM were asked to identify their foreign source dependencies. (Major was defined as 80%, by value, of the total bills-of-materials). Their responses, valid as of Spring 1985, were supplemented by similar responses to a March, 1986 Navy study of the same area. The total response rate was 60% by number of companies and roughly 80% by value-added. Additional instances were culled from individual PGM studies sponsored by the Naval Air Systems Command (Sparrow and HARM missiles).

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14. Joint Service Production Base Analysis: Precision Guided Munitions, 1985, hereafter known as the PGM Study.

The list was then split in two: dependencies specific to the integrated circuit (IC) industry and everything else. This industry was separated because dependencies were common across all ICs and were pervasive within the industry. Examples included IC assembly, packages, glass masks, wafers, and transistor metal cans. Mitigating such dependencies was a matter of determining whether domestic capacity sufficed to handle military needs in an emergency. By contrast, the other dependencies were generally weapon-specific and their resolution was particular to the item examined.

For specific instances of foreign sourcing, we contacted those firms which cited these instances and inquired more deeply into the source and nature of these dependencies. This, when coupled with calls to selected producers, allowed us to estimate how much inventory would be required to buffer the domestic base from a cutoff of overseas supplies. Similar methods were used for other problem solutions where appropriate.

Findings

Although foreign-sourced parts constitute only one to two percent of a typical PGM's value, the industry's reliance on overseas sources is widespread. Of the almost 300 vendors examined in the various PGM studies, over a quarter claimed to be dependent on overseas components or processing. After close examination of their claims, they were reduced to 27 instances of dependencies. These may be grouped into five categories:

a. Subsystems--high-cost items bought abroad directly by a prime contractor or the propulsion maker: 8 instances.

b. High Incidence Subcomponents--those which more than one subcontractor has to buy abroad because domestic sources are uncompetitive in quality or price: 7 instances.

c. Integrated Circuits (ICs)--a sector riddled with dependency, from assembly to packaging and materials.

d. Low Incidence Subcomponents--those which only one respondent reported buying abroad: 7 instances.

e. Materials--often unavailable in sufficient quality from domestic sources but which should be covered by the National Defense Stockpile: 4 instances.

Also reported are those subcomponents which are <u>incorrectly</u> identified as foreign source dependencies.

Of the five categories, the subsystem dependencies would cost most to fix. A buffer stock of almost $9 million would buy subsystems (and/or their subcomponents as well) to cover the time it would take the current domestic source to make up for the loss of its overseas competitor. Although many items are dual-sourced (and thus not dependencies, strictly speaking) the inability of domestic producers to increase shipments immediately would mean disrupted PGM deliveries until some domestic source had increased production to compensate. In that most PGM production is also constrained at the prime contractor's delivery stations, lost production means lost capacity, and not just later deliveries.

Affected subsystems include five mechanical components purchased by the prime guidance and control contractors. They are launch tubes, extrusions, actuators, gear motors, and castings. If their suppliers are cut off, production would cease for three to six months. Also included are rocket motor cases for the Harpoon, HARM, and Skipper missiles. The first two are also produced here, but there is no one formally qualified for the latter (although many are technologically capable). A cutoff of rocket motor cases would disrupt schedules for up to nine months.

The more critical problems come from a cutoff of those subcomponents common to multiple systems, requiring a buffer stock of $2.8 million to mitigate. This could disrupt schedules for at least a year with some parts (field effect transistors, ferrite cores) and six months to a year on others (gallium arsenide transistors, sapphire, butane triol). Two items (high-specification glass and high-purity silicon) could be produced domestically without significant disruptions but nevertheless present risks due to the uncertain viability of their supplier base.

ICs, used in all PGMs, have dependency problems all their own, almost all generic to the industry and not military programs as such. The analysis assumes that, in a crisis, defense demands would have the first priority in competing for limited production resources. That being the case, the question is whether the bottleneck resources would stretch to fit military demands. The answer is a qualified yes. Domestic sources could assemble at least 60 million chips a month, enough to cover four times current military needs (albeit at reduced burn-in and testing specifications), and, with a modest stockpile of plastic and metal leads and ceramic package materials, could package these chips as well. Other critical materials such as metal transistor cans, glass masks and silicon (for wafers) could be stretched until domestic sources proved adequate. (Future dependencies arising from perceived weaknesses in the domestic IC industry itself are addressed in a later section.)

The low incidence subcomponents sourced abroad are diverse and require that only $400,000 worth be prestocked. Included are ball screws, copper-liner preforms, bearings, molybdenum foil, printed wiring board plating bath, springs, pivots, and specialty chemicals.

As for materials, the cost of additional inventory, to be held by PGM producers, would also be modest. Because there is a National Defense Stockpile which is supposed to cover these needs, no separate stockpile calculations were made. However, two of the four materials, samarium and indium, have no stockpile goals; a third, germanium, has only had a goal for two years.

See Appendix A for a detailed analysis.

Fixing the Problem

Tables 8 and 9 summarize the cost of buffering the PGM industry against a cutoff from overseas.

Several features of the estimates in Tables 8 and 9 deserve note. The salient one is how low the total is. Based on a forty-hour week, the PGM industry consumes $12 million in only four hours. For just this, items most critical to the CINCs can have their current production ensured even if all overseas sources were cut off. Also, most of the major expense is for parts for which domestic producers are active but supply only a fraction of the total component requirements. Those sourced only overseas are a small fraction of the total. Another interesting datum is that half of the cost is for one program alone, the HARM missile.

Preparing for Surge: The estimates in Tables 8 and 9 provide insurance against disruptions in current production schedules. What if the aim were to ensure that an overseas disruption would not prevent surge schedules from being met? Table 8 shows that the additional sum to ensure surge schedules would be even more modest, $2.7 million.

Why so little? The major reason is that domestic bottlenecks themselves keep surge production from rising significantly in the absence of specific industrial preparedness measures. Based on the Navy PGM study, a rough guide is that industry, as currently prepared, begins accelerating production as soon as nine months but that prime contractor and random system bottlenecks prevent production from rising beyond 150% of the base rate. Hence, the difference between surge and base schedules is minor during the time period at greatest risk of disruption. Since most of the foreign source dependencies are fixed early, by the time production does rise, they are no longer holding back the rest of the system. Most of the subcomponents sourced overseas are not on the critical path per se. Some subcomponents are so far off the critical path that the additional lead time

Table 8

Mitigation Costs by Affected Component
($,000)

ITEM	SYSTEM	SOURCE	IMPACT	BUFFER STOCKS FYDP	SURGE*
Silicon FET	Radar	Japan	12+mo (all)	1500	1000
Ferrite Cores	Radar	Germany	12+mo (all)	150	100
Rocket Mtr Case	Skipper	UK	9 mo (all)	1600	200
Rocket Mtr Case	HARM	UK	7 mo (60%)	4800**	1000
Rocket Mtr Case	Harpoon	UK, Austrl.	7 mo (all)	600	0
GaAs FET	Radar	Japan	6+mo (all)	200	100
Butane Triol	***	Germany	6+mo (all)	600	50
Sapphire	Sdwr et al	Switzerland	6 mo (all)	100	50
Copper Preform	Copperhead	Switzerland	6-mo (all)	250	50
PWB Plating	HARM	UK	6-mo (all)	50	20
Springs, Pivots	Phoenix	Germ, So Af	6-mo (all)	1	0
Ball Screws	Patriot	UK	3 mo (all)	30	10
Precision Optics	****	Japan, Germ.	3 mo (all)	250	50
Actuator Mtr	HARM	UK	3 mo (75%)	1100	0
Gear Mtr	HARM	UK	3 mo (50%)	100	0
Castings	Standard	Israel	3 mo (50%)	50	0
Radome Chemicals	Radar	Mexico	3-mo (all)	50	0
Molybdenum Foil	Patriot	Austria	2 mo (all)	2	0
Launch Tube	Stinger	Israel	2 mo (75%)	100	0
Extrusions	Harpoon	Australia	2 mo (50%)	300	0
Bearings	Standard	Overseas	2-mo (all)	10	0
Ingtd circuit Pts	All	E. Asia	varies	200	50
TOTAL				12043	2680

*   additional stocks needed to hit 150% of rate in nine months
**   includes $800,000 in additional tooling
*** Standard, Patriot, Maverick, Sidewinder et. al.
**** Sidewinder, Maverick, HARM et. al.

Table 9

Buffer Stock Costs by Subcomponent Type

Subcomponent Type	Buffering Cost
Subsystems	$ 8,650,000
High Incidence Subcomponents	$ 2,800,000
IC Dependencies	$ 200,000
Low Incidence Subcomponents	$ 393,000
TOTAL	$ 12,043,000

required to find a domestic source can be afforded within the times required to accelerate the production of the longest lead item in the production flow.

<u>Vulnerability Versus Dependency</u>: Since not all dependencies are vulnerabilities, an assessment of the latter would be heavily influenced by the sources involved and the chances that the US would be cut off from them. As it happens, virtually all of the foreign sources are allies or friendly neutral countries. Except at the materials level, no third-world country is represented; virtually none of the foreign source dependency risk is associated with the type of conflicts which have characterized the post-WWII era. Table 10 regroups the cost of buffering PGM schedules by the country which currently provides the relevant components and subcomponents.

Table 10

<u>Buffer Stock Costs by Source</u>

Source Country	Buffering Cost
United Kingdom	$ 7,980,000
Japan (and miscellaneous SE Asia)	$ 2,025,000
West Germany	$ 905,500
Australia	$ 600,000
Switzerland	$ 350,000
Israel	$ 150,000
Mexico	$ 20,000
Austria	$ 2,000
South Africa	$ 500
Unknown	$ 10,000
TOTAL	$ 12,043,000

Thus, if the U.K. were not considered a country at risk, only four million dollars' worth of inventory would be needed for the same effect. Similarly, if the only serious risks are countries in Central Europe or in the third world, the inventory costs are further reduced to little over $1.6 million.

<u>Caveats</u>: As in all such exercises, the total estimate must be qualified by consideration of missing factors. The most basic is that the sample is not 100% complete. The companies on the original supplier list from the prime contractors only supply 85% to 90% of the materials used in PGM production because they did not include all the minor piece-parts. Only 60% of the suppliers (80% by value) responded to the surveys and no separate surveys were done below the prime contractors' immediate suppliers (many

suppliers, however, would be aware of dependencies among their own suppliers). Finally, many respondents appeared unaware of or chose not to report on their foreign sourcing constraints.

Such coverage, however, was sufficient to capture almost all of the big subcomponent dependencies and most of the multi-program dependencies (only one respondent out of many affected needed to report the latter for it to be measured). It is thus estimated that the study's coverage was 90% for subsystems, 80% for high incidence subcomponents, 100% for the IC dependency problem, and 40% for low incidence subcomponents. Extrapolated to the non-respondents, an overall figure of $15 million would be a comfortable upper bound for the total.

The more critical factor was the estimate of how long it would take for a domestic source to replace a foreign one. Where a domestic source is qualified, the current estimate of lead times under emergency conditions is probably reliable. Where no domestic source is capable of producing to a certain quality specification, any such estimate is necessarily soft. Until domestic sources actually have to replace foreign ones, no one will really know.

Finally, some of the quantity numbers for current production rates may be soft, particularly where some estimate had to be made of what the PGM sector's share of military usage was. In general, such estimates used are conservative (i.e. biased upwards).

Conclusions from the PGM Case Study

Notwithstanding the many differences between the PGM sector and the rest of the defense industry, this case study suggests several important points about the phenomenon of foreign source dependency.

First, it _is_ possible to get a handle on the entire foreign source dependency problem, particularly when producers are aware of the legitimacy of the Government's concern. While a full one hundred percent coverage of the industry would have been impossible, enough information was collected to demonstrate the pervasiveness (high) and the total solution cost (low) of the foreign sourcing problem. Further study to scope out general policy recommendations is _not_ needed as it will not improve the estimate enough to matter. For systems not covered here, sufficient data can be collected without efforts significantly more complicated that those which have been tried to date. Prior contradictory conclusions (an IDA semiconductor study,[15] and the JLC study) are in error.

The most salient lesson, from a policy viewpoint, is that the cost of insurance is small, only a few percentage points of one year's production. Of the total $6 billion spent every year for precision guided munitions, roughly one to two percent is spent abroad. $15 million to prestock critical subcomponents would ensure the continuity of current production in the face of an unexpected total foreign source cutoff, the most severe condition.

The greater surprise is not how much foreign source dependency exists, but how little. Compared to the one to two percent figure cited above, the manufacturing sector, in general, probably gets ten to twenty percent of its value-added from abroad. Comparable figures are fifteen to twenty-five percent for automobiles, ten percent for test equipment, and a similar ratio of non-military-specification ordnance such as sonobuoys.

Why so little dependency? One reason may be that the requirement to qualify component producers makes it much easier for prime contractors to deal with domestic suppliers (most of which are military-oriented to begin with) than foreign ones. The military market, even at the subtier level, requires a long learning curve before entrants are sufficiently steeped in the way the Department of Defense does business. Such investment is infeasible for most potential overseas sources at the second-tier and many even at the third-tier (where DoD's influence is muted). Another reason is that most producers do not, themselves, want to be dependent on overseas suppliers and have said so explicitly. Not all producers feel this way, however, and so the insurance provided by one supplier is vitiated by the lack of insurance from another supplier who is not so bothered by foreign sourcing.

No one reason dominates as the cause of foreign sourcing but several individual reasons recur. For those dependencies where domestic substitution would be lengthy, the primary cause is the inability of domestic producers to meet required quality control standards, particularly where materials quality matters. Examples of this problem occur in ferrites, silicon FETs, and IC materials (especially packaging). A second cause is that domestic volume (or world volume, for that matter) for some items is too small to interest domestic manufacturers. Where there is only one world producer, it is no more likely that the producer is domestic than foreign. Examples of this include sapphire, butane triol, and titania (a radome chemical). Economics, a third cause, accounts for foreign sourcing in those areas where

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15. Institute for Defense Analyses, Technical Assessment of US Electronics Dependency, March 1985.

business is dominated by commercial markets and considerations. Examples included GaAs FETs, glass, IC assembly, and bearings. Finally, some overseas defense firms (Royal Ordnance (UK), Lucas (UK) Schwarzkopf (Austria), IMI (Israel)) have found profitable niches in the domestic military market, and are frequently second sources on selected subsystems. Although the latter is not a dependency, per se, an unanticipated cutoff would interrupt production schedules just the same.

Not to be overlooked is the dynamic nature of the dependency problem in both directions. Several subcomponents which were sourced overseas a year or two ago are now or will soon be purchased domestically. Examples include the standard missile rocket nozzles, high-purity silicon, and certain transistor packages. In other cases movements go both ways; at least one IC producer is moving its assembly back home, while several others are dismantling assembly capacity and preparing to go offshore. In yet other cases, such as rocket motor cases, foreign sourcing appears to be a growing trend. Where some producers are busy trying to qualify domestic sources to eliminate potential dependencies, others are reevaluating foreign suppliers to improve product economics.

The overseas sourcing of PGM subcomponents, while it is a relatively small percentage of total value-added, is nonetheless capable of leading to sharp schedule disruptions in the event of a foreign source cutoff. The overwhelming bulk of foreign sourcing takes place in what are currently Allied or friendly neutral countries. Many of them, particularly those situated near the Iron Curtain may, be considered at risk in a large conventional conflict.

For roughly \$12-\$15 million (mostly in additional inventory) this \$6 billion sector can be protected against an unanticipated cutoff from overseas sources. The insurance premium rises to only \$15-\$20 million to insure against disruption of surge requirements. Since this cutoff would, more likely than not, occur in the context of a major conventional conflict, it would be precisely when PGMs were most needed that their production is at greatest risk. The large fraction of investment for parts --that would have to be bought over the production cycle anyway-- can otherwise be recovered at the end of the weapon's production lifetime. Should this sum not prove immediately affordable, the cost could be cut in half by omitting the HARM program from schedule protection, or be cut by two-thirds by not insuring against a disruption of supplies from the United Kingdom.

Implementation and Further Considerations

Rather than having the Government purchase the buffer stocks outright, it may be more effective for the prime contractors to demonstrate that they could continue production at scheduled rates even with a total overseas supply cutoff. Program costs would have to reflect such costs in either case, but specifying a requirement through a contract rather than by line-item purchase allows producers greater flexibility and could perhaps lower costs substantially. Government's role would be limited to spot-checking compliance and specifying exceptions (e.g. that the National Defense Stockpile is available, that IC assembly capacity will be allocated in a crisis, and/or that IC packaging specifications could be altered).

Industry could demonstrate continuity through:

a. buying additional inventories;
b. demonstrating that its overseas sourcing does not create a dependency;
c. showing that the affected item, through prone to schedule disruptions, is not on the critical path; or
d. evaluating all economies, imposed and extant, and deciding to buy more domestic.

The latter solution may, particularly with a subsystem sourcing decision, be significantly cheaper than buying inventory.

The more general impact of foreign sourcing, that of reducing domestic surge capacity, is relatively minor compared to all the other constraints on capacity. A sector, for instance, which is at full capacity for peacetime deliveries is, in the end, no more responsive than one which is supplying only half the military's needs but is working at half capacity. In general, industry's ability to expand quickly is not assured. Too many critical sectors are working at or near capacity to satisfy current military demand; the knowledge and resources required to shift production to alternative sources will not be instantaneous.

This study argues that very little investment would be required to preserve production schedules, and that such investment would be very cost-effective. Comparable work done for the Navy's production analysis suggests that, although more investment would be required to facilitate such production expansion, investing for surge is also cost-effective. For seven core PGM programs, as example, every weapon diverted into investment in opening bottlenecks would allow fifteen additional weapons to be built in the first year and a quarter of a build-up. The leverage available from such investment is substantial.

Properly conceived, therefore, a concern over foreign source dependency is but one subset of maximizing industry's contribution to war fighting.

SECTION FOUR

Mitigating Foreign Source Dependence in a Long War Scenario: A Case Study of Materials Supply and Demand

Over the last forty years the world economy has grown increasingly interdependent. As it has done so, the American economy has taken advantage of cheaper and more abundant materials from abroad.

In the process the United States has become more dependent on other countries for a large share of its energy, metals, and minerals supplies. Under normal conditions, this transition would, itself, not be a problem per se. The United States gains whenever it can trade something it makes efficiently for something others do cheaper. However, if the US were cut off from other countries for a significant period, the reduction in key materials imports could disrupt industrial production. Were this cutoff associated, as is quite plausible, with war, defense production could be crippled just when most needed for national security.

The presence of vulnerability is clear. At present, the Federal Government holds large stocks of oil, metals and minerals against just such contingencies. In many industries excess capacity abounds even as (or more precisely because) import levels are so high. All this considered, there is substantial disagreement on whether the US industrial base is adequately protected. Take the National Defense Stockpile, with $10 billion dollars' worth of stocks. In 1980, FEMA estimated the requirements for strategic materials to support the economy during a large-scale three-year conflict to be $16.6 billion. More recently, the NSC determined that $0.6 billion total would suffice. Numbers, unfortunately, matter in understanding the basic nature of the country's dependence risk.

Scope

The fundamental inquiry of this section is the extent to which the North American economy can withstand a complete cutoff of all imports in the context of a four-year conventional war. Are existing stocks large enough to support defense mobilization without bringing the rest of the economy to a halt? Or, instead, are they excessive to every plausible scenario? Where, in fact, could North America satisfy its energy, metals and minerals needs?

To explore these questions, this section estimates supply and demand requirements for energy, metals, and minerals under a basic wartime scenario. The ground rules are akin, but not identical, to those used for calculating National Defense Stockpile goals. They assume a four-year cutoff of imports and exports outside North America (the US, Canada, and Mexico) in the context of a major conventional war which absorbs $1.2 trillion (constant 1985) dollars from the US economy. An excursion from that scenario assumes that North and South America can access each other but not the Eastern Hemisphere.

No attempt will be made to argue the likelihood of a major conventional war or an extended North American cutoff in that context. Rather the scenario is used to represent the most analytically tractable high-risk situation, one which describes the consequences of North America thrown back on its own resources in order to survive.

One may in fact note the possibility of worse cases. If Europe, North American and Japan were accessible to each other but to no other region, North America's mineral supplies would be stretched even more than they are now. Only over the longer term would the greater technology resources available from other developed regions enhance the potential for substitution. But that scenario appears implausible, not merely unlikely.

The notion of adequacy, which is central to this discussion, needs clarification. Wars cause disruption. One costing over a trillion dollars will require consumption to decline and austerity to be imposed. The proper goal of a mobilization materials policy is to ensure that the degree of displacement is governed by the broad macro forces and is not unnecessarily exacerbated by a shortage of materials. Which sectors to cut back will be influenced by the common-sense notion that reductions in civilian demands should free up the same kind of industrial resources that additional military demands will require. To pay for weapons, we should use policies which best liberate industrial capacity (e.g. for consumer durable goods) as well. Once the broad shifts are made, materials policy should support these changes and not drive them of their own accord.

It should be further noted that resolution of materials shortfalls will leave many other gaps in the industrial base, from forgings to precision bearings, from machine tools to semiconductor materials. In emergencies, some can be fixed in months, some cannot. Some weapons may have to be redesigned to take advantage of what capacity exists. What also matters is that some of the upstream bottlenecks (e.g. nonferrous forgings) will make the presence of materials bottlenecks (e.g. titanium) irrelevant. Where intermediate shortfalls are significant to one or another material, they will be noted.

Finally, this section is not written to generate numbers for their own sake but, more importantly, to illustrate the factors which influence our materials vulnerability. Under the circumstances, precision up to the nth decimal place is unnecessary. Getting within five to ten percent will do.

The War Scenario

The nation's response to an extended cut off would be to fall back on its own resources: the industrial infrastructure of the United States, Canada, and Mexico; the current stockpiles of petroleum and minerals maintained by the Federal Government; and policy instruments available to shift economic demand from civilian consumption to military requirements.

The excursion basis for the war scenario is the 1985 economy. From that base, the impact of war on the size and composition of GNP are calculated and the demand and supply implications of this shift are assessed. To simplify the excursion it will be assumed that the economy does not grow for the duration of the war. At first, this seems illogical. Since economies do grow over time, the assumption that they would not seems to understate the demand for materials. Since 1973, however, the materials intensity of the economy has declined just as fast or faster as the economy has grown. The net effect has been a flat demand for materials, or one which has even dropped. Table 11 illustrates this by comparing real GNP to energy, steel, aluminum, copper and chromium demand in the three most recent business cycle peak years. There is little reason to believe that such trends will not continue into the foreseeable future. Rather than try to model the countervailing impacts over the course of war, this study assumes no change in current trends.

Table 11*

Basic Trends in the Domestic Demand for Selected Materials

	1973	1979	1985
GNP	2744	3192	3585
Energy	74.3	78.9	73.9
Steel	112600	104700	103200
Aluminum	6170	5350	5170
Copper	2210	2350	2150
Chromium	550	550	400**

* GNP in billions of 1985 dollars, energy in quadrillion BTU and metals in thousands of metric tons.

** Adjusted upward to reflect imports of chromium-bearing steels.

The world, of course, is not static. The 1986 drop in energy prices and the continued weakness of commodity prices can be expected, over time, to lead to less domestic supply and more domestic demand. To the extent that these factors operate over a long time, vulnerability may rise. But other factors could also come into play--technologies change, mines open and close, political developments affect the likelihood of overseas emergencies, et cetera. The salient observable trends which may change the basic outlook will be noted.

The difference between peacetime and wartime can be described as the broad redeployment of resources. In this scenario military spending, $260 billion (6.5% of GNP), rises to $1,200 billion (27% of GNP), a difference of $940 billion. This compares to roughly 40% of the GNP for WWII and 15% for the Civil War, Korean Conflict and World War I. Why 27%? For two reasons. One is that the quantities involved are consistent with the Defense Guidance scenarios, the JCS Planning Force and the Navy's mobilization production targets (see below). The second is that beyond this total, serious questions of the polity's ability to support austerity arise. Even though WWII took 40% of the GNP, because the US was in a depression when the war started, the overall level of civilian consumption did not have to decline sharply.

These basics given, we next estimated the relative magnitude and characteristics of the higher military spending, the potential increase in GNP (which pays for part of them), and the easiest places to reduce expenses (which pays for the rest of them).

Expenditures for weapons were estimated using roughly the same procedure used by the Navy to calculate its mobilization production targets. Material requirements were determined by the production required to overcome attrition and build a force capable of prevailing in a conventional conflict. Items which either cause attrition (ammunition and precision munitions) are expanded the most, followed by items which suffer from attrition (vehicles and aircraft), and lastly items which support operations but which themselves are not attrited so much (ships, strategic forces and other). This war builds to a combat base roughly three times current force levels; this corresponds to a threefold increase in the operations budgets.

The first step is to estimate a scenario GNP and then distribute it. The scenario increase in GNP, 10%, follows, in part, from assuming an unemployment rate of roughly 4% (as it averaged during the Vietnam war) rather than 7% as it was in 1985. This translates into a 6% increase in GNP if the relationship between the two remains what it was over the last fifteen years. The other 4% comes from adding people now outside the work force. This contributes little because the labor force participation rate (military plus civilians available for work) for women (55%) is already far higher than it was in World War II (36%). Further increases will be harder to find. The most likely source may be from those who have recently retired or were planning to over the period of the conflict. Male labor force participation rates (77%) were higher thirty years ago (85%). All this would add another 4% to GNP, for a total increase of 10% higher than the business cycle peak level of 1985.

In comparison the Korean War GNP was 7% higher than its peacetime business cycle peak would have been (as determined by interpolation from 1948 to 1956). World War II's GNP was roughly 30% higher than a peacetime full employment GNP would have been, as determined by interpolation from 1929 to 1948. However, this 30% increase must be carefully considered. Much of the 30% is statistical in that forty percent of the output reflect items not previously produced. The other 60% was measured in nominal terms--disturbed by price controls. There was also a large, but unrepeatable, increase in the total labor force participation rate from 55% in 1940 to 63% in 1944, as well as the recovery of productivity after a long depression. Thus the 10% increase in war over peacetime GNP is more typical of what a large war might produce in the 1980s rather than the 1940s.

The next task is to see which sectors are displaced by war production. History suggests to postpone replacing existing goods (which suggests less construction and fewer durable goods) is easier and happens with less impetus than doing without day-to-day requirements (which suggests maintaining services and nondurable goods). Construction and durable goods expenditures are the easiest expenses to postpone. An 80% reduction in residential construction and a two-thirds reduction in consumer durables would free $390 billion. Similar reductions can be applied against commercial construction (e.g. fewer new office buildings) to yield another $60 billion. The other resources can best be freed by squeezing here and there. Since war demands would force conversion of much of the nation's airline fleet to military uses, what remains would be sharply limited air transport, less fuel consumed, and no market for new commercial aircraft--all this saving billions. Cutting back on vehicle miles travelled would also be required as an energy-saving move. Other cuts are possible from decreased needs for social services.

Import substitution also has to be factored in. In 1985, the United States consumed roughly $80 billion more than it earned ($60 billion net from outside North America). Without imports, consumers have to do without or get their supplies from the domestic base. If net imports are reduced to $20 billion the additional $60 billion in GNP must be made up from the rest of the economy (assuming that austerity has already been provided for as discussed above).

Table 12 breaks the 1985 economy into 21 demand sectors. The first column is an estimate of how final-demand expenditures were actually distributed by category; the second column is how these expenditures might be distributed to mobilize for the war scenario.

Table 12

1985 Wartime Versus Peacetime Scenario
(in $billion)

#	Subcategory	Peacetime	Wartime	Difference
	Household Consumption			
1	Services	1340	1300	- 40
2	Energy	230	200	- 30
3	Other Nondurables	680	680	0
4	Automobiles	120	40	- 80
5	Other Durables	190	60	- 130
	Housing			
6	Construction	190	40	- 150
7	House Durables	50	20	- 30
	Business Investment			
8	Construction	160	100	- 60
9	Aircraft	10	0	- 10
10	Other Transport	50	40	- 10
11	Equipment	240	240	0
	Government			
12	Non-Defense	550	500	- 50
13	Military Operations	170	500	+ 330
14 - 21	Military Procurement	90	700	+ 610
14	Ammunition	3	90	30X
15	Precision Munitions	8	80	10X
16	Tracked Vehicles	6	60	10X
17	Helicopters	4	40	10X
18	Combat Aircraft	22	220	10X
19	Cargo Aircraft	4	40	10X
20	Ships	10	40	4X
21	Strategic & Other	33	130	4X
	Changes in Inventory	10	0	- 10
	Net Exports	- 80	- 20	+ 60
	TOTAL	4000	4400	+ 400

The basic calculus is that additional military expenditures ($940 billion) plus trade and inventory adjustments ($50 billion) can, in part, be paid for by higher GNP ($400 billion). The rest has to be paid for by shifting resources from construction ($230 billion), consumer durables ($240 billion), transport equipment ($20 billion), public services ($50 billion), private services ($40 billion) and energy ($30 billion). Nondurable goods production and business equipment investment stay constant.

Energy

In 1985 the US economy used 73.9 quads (quadrillion BTU) of energy and produced 64.8 quads. Most of the difference was imported from beyond North America. This included oil imports of 9.0 quads, natural gas imports of .9 quads, electricity imports of .4 quads, counterbalanced by net coal exports of 4.2 quads. There were also changes in inventory levels over the year. Were North America isolated, the United States would face a serious energy shortfall, most of it in oil. If 1985 conditions could prevail indefinitely, the shortfall could be managed, as this section argues. Over time, the sharp drop in oil prices, if continued, is likely to lower domestic supply and raise domestic demand so as to make the shortfall progressively harder to manage.

The energy problem per se is really the oil problem; the oil problem in turn is largely a motor fuels problem. As such, most of what would be required in terms of demand (to match reduced supplies) would have to come from the transportation sector; very little is available from all other activities. To show this, Table 13 breaks down 1985 energy usage into four fuels (oil, gas, coal and other) and four basic usage groups (heat, engines, electricity and materials).

Table 13

1985 Energy Supply and Demand
(in Quads)

Demand	Oil	Gas	Coal	Other	Total
Heat	5.8	13.4	1.7	0.0	20.9
Engines	20.4	0.5	0.0	0.0	20.9
Electricity	1.1	3.2	14.5	7.7	26.5
Feedstocks	3.6	0.7	1.3	0.0	5.6
TOTAL Demand	30.9	17.8	17.5	7.7	73.9
Domestic Output*	21.2	17.0	19.3	7.3	64.8

* The difference between demand and supply is made up by net imports plus stock changes.

The war scenario entails several major changes, a cutoff of sources beyond North America, a ten percent higher GNP, a transfer of final demand from civilian uses to military ones, and everything else (including policy measures to fill the gap).

A cutoff of sources outside North America is what creates the oil supply problem in the first place. In 1985, oil producers in the United States and Canada were selling up to their full pumping capacity; Mexico was selling most of what it could produce. A North American cutoff would force all of Mexico's exports north (on the theory that the same forces blocking imports are also blocking exports); in rough terms this supply is 3.0 quads (1.5 million barrels/day). Since Canada's net oil balance is currently zero, only a small quantity of additional supply should be expected from the north.

Table 14

The Impact of Higher GNP on Oil Usage
(in quads)

	1979		1982		1985		1985 (+10% GNP)
Residential/ Commercial (all fuels)	3.4	(11.3)	2.4	(9.2)	2.6	(9.6)	2.8
Industrial (all fuels)	3.1	(14.4)	2.1	(11.6)	1.7	(11.4)	2.0
Electricity (all fuels)	3.5	(24.4)	1.6	(24.3)	1.1	(26.5)	1.2
Motor Gasoline	13.5		12.5		13.1		14.4
Commercial Jets	1.6		1.4		1.8		2.4
Military Jet Fuel	0.6		0.7		0.7		0.7
Asphalt	1.1		0.8		1.0		1.5
Petrochemicals	3.4		2.5		2.5		3.1
Bunker Fuels	1.0		1.0		0.8		0.8
Other Engines	4.1		3.8		4.0		4.4
Still Gas/Coke	1.7		1.5		1.6		1.8
TOTAL	37.0		30.3		30.9		35.1

A 10% increase in GNP, in and of itself, would be associated with an increase in the demand for energy. Table 14 illustrates the impact of the 1982 recession, which decreased GNP by roughly 7% relative to the 1979-1985 trend. This decrease, by category, was reversed and increased to simulate the impact of a 10 percent GNP gain. For each sector, usage was projected by comparing actual 1982 consumption to a synthetic figure generated by assuming that demand would have otherwise grown (or shrunk) geometrically between 1979 and 1985. This recession-induced deviation was then multiplied by 150% and applied to the actual 1985 oil usage to get a projected high-GNP 1985 fuels usage. The results show that a 10% cyclical rise in GNP can be associated with a 4.2 quad increase in oil demanded. (Bear in mind that the secular growth in GNP since 1973 has been associated with declines in energy requirements.)

The shift from civilian to military outputs would have its greatest impact on the demand for jet fuel. A threefold increase in military jet fuel demand (from 0.7 to 2.0 quads) could be offset by reducing commercial jet fuel demand from projected levels of 2.4 quads to 0.6 quads (versus 1.8 quads in 1985).

The war scenario introduces other shifts. A foreign source cutoff would also reduce requirements for ship bunker fuel (from 0.8 quads to perhaps 0.2 quads). For petrochemicals cuts in commercial goods production would also more than offset higher military demands to reduce oil demand by 1.0 quads. All the other industrial shifts together net a savings of 0.5 quads of oil demand. Finally the reductions in construction portend a comparable reduction in projected asphalt demand from 1.5 quads to 0.5 quads.

Policy and/or price measures could conserve oil at the expense of more abundant fuels, such as natural gas and electricity. Natural gas could replace roughly 2.0 quads of oil but no more, because it can substitute for oil only in heat or electrical generation applications--a total of 7.0 quads (7.6 quads, after GNP increases). Of these, 1.6 quads are supplied from refinery by-products (coke and still gas) which having been produced might as well be used. Also much of the remaining 5.4 quads (particularly liquid petroleum gases) are consumed in sites quite removed from gas utility lines. Even getting as much as 2.0 quads displaced would require the extension of gas lines, particularly in New England. That noted, natural gas supplies themselves should be adequate for the task. Current capacity is roughly 20 quads, with another 2 quads available from Canada and Mexico (given pipelines). Demand was 18 quads; in the war scenario base gas demand rises to 19 quads. This allows up to 3 quads of oil to be replaced by gas. Up to two more quads of gas can be liberated by wheeling electric power from underutilized coal plants in the Midwest to natural gas using regions in the Southwest.

In addition, perhaps another 0.5 quads, but little more, could be realized by a switch from oil to electricity for residential and commercial space heating applications. From 1979 to 1983 alone, the number of oil-heated houses declined from 20 million to 16 million units, a proxy for the (reduced) potential for heating convertability. With direct oil consumption cut, the demand for refining fuel could be shaved by 0.4 quads.

Additional supply from oil drilling is possible. From 1979 to 1981, when oil prices tripled, the number of wells completed also rose, by 80%. Prior to that point, from 1973 to 1979, Lower 48 oil production was steadily declining at roughly 0.6 quads each year. With higher oil prices between 1980 and 1985, however, crude oil production in the lower 48 rose by an average of 0.1 quads a year. This experience suggests supply incentives may result in a further annual production increase of 0.7 quads every year, but (because of a one-year lag) only in the second year and beyond. Over a four-year period, 4.2 quads would be added to supply. Currently, 3.3 quads is available from the Strategic Petroleum Reserve.

As Table 15 indicates, this still leaves a gap of 2.7 quads.

Table 15

Oil Supply-Demand Balance in the Scenario

	Supply	Demand
Basic Balance (1985)	21.2	30.9
Redirected North American imports	+ 3.0	
Additional Oil Supply	+ 1.0*	
Strategic Petroleum Reserve	+ .7*	
Additional Demand from + 10% GNP		+ 4.2
Decreased Demand from Conversion to Military Goods		- 1.5
Additional Military Jet Fuel Demand		+ 1.3
Reduced Civilian Sectors		- 3.4
Substitution of Gas for Oil		- 2.0
Substitution of Electricity for Oil		- 0.5
Indirect Refining Savings		- 0.4
Adjusted Balance	25.9	28.6

(* per year over four years)

The enumerable steps having been taken, what remains is to find the easiest places to cut back demand from the economy's natural inclination. Thus instead of 14.4 quads used for motor fuel (compared to 1985's 13.1 quads and 1986's 13.5 quads) supply shortfalls would constrain consumption to 11.7 quads. Reductions of this scale are probably manageable through either direct price increases or rationing.

As such, it is still possible, though just barely, to support a wartime economy with oil even after a complete cutoff of sources outside North America.

What if South American oil was available: Even if the rest of the world were cut off, geopolitical realities make it highly unlikely that the US would be restricted from Caribbean or South American oil sources for any significant length of time. In that case, perhaps as much as 500,000 more barrels a day, or 1.0 quad, would be available to the North American market. This would alleviate the supply shortfall but the basic nature of the problem remains.

Trends: Table 16 compares supply and demand trends from the mid-1970s (when oil was roughly $15 - $20 per barrel in today's dollars) and the early 1980s (when oil was roughly $30 to $40 per barrel in today's dollars). Had oil prices remained constant in real terms from the early 1980s onwards it is likely that the net oil balance would have improved by as much as 0.6 quads a year.

Oil production in 1986 fell 1.2 quads from what it was in 1985. Meanwhile demand, mostly for motor fuels, rose .4 quads. There was also some shift from gas to oil use in industry and electricity production, but not enough to change the underlying requirements for oil in a crisis. A 1986 war scenario would require gasoline demand to be reduced more, from 13.5 to 10.5 quads.

Table 16

Annualized Trends in Energy/Oil Production and Demand*
(in quads)

	1973-1979		1979-1985	
Oil Supply		- .6		+ .1
Motor Fuels	- .3		+ .1	
(oil share)		- .3		+ .1
Heat Fuels	+ .3		+ .9	
(oil share)		+ .1		+ .2
Electricity	- .8		- .3	
(oil share)		.0		.0
Materials	.0		+ .3	
(oil share)		.0		+ .2
Net Oil Balance		- .8		+ .6

* A reduction in demand is a plus in the balance; an increase in demand is denoted as a minus.

Over the longer run, the lower oil prices are likely to reinforce declining production trends and possibly bolster demand as well. During the mid-1970s, domestic oil production declined and there was a small positive increase in oil-intensive energy uses; the net increase in oil import requirements from these two trends alone (ignoring interfuel substitution) was 0.8 quads/year. Were this trend to recur, the 4 quad shortfall calculated above would increase to 7 quads by 1990, an amount increasingly difficult to make up through demand rationing.

A Persian Gulf Excursion: A cutoff of the Persian Gulf and COMECON countries may be a more likely consequence of war than a complete cutoff of North America from everywhere else. Table 17 compares the production, capacity and demand for the rest of the world to see if this creates a more stringent supply shortage for the United States in wartime.

Table 17

1985 Supply and Demand
(in quads)

Region	Production	Capacity	Consumption
Persian Gulf States*	20	40	3
Soviet Bloc Countries	27	27	24
Rest of World	66	71	86
TOTAL	113	138	113

*Saudi Arabia, Kuwait, UAE, Iran, Iraq, Qatar, Bahrain

This excursion subtracts 20 quads of supply from the rest of the world. Excess capacity in OPEC countries outside the Gulf could make up 5 quads (2.5 million barrels/day), but this would still leave a shortfall of 15%. Although this initial shortfall is comparable to that experienced by the United States under the war scenario, the latter remained after various demand management provisions were employed. As such, the Persian Gulf excursion has to be considered the lesser case, and easier to deal with.

Metals

Metals adequacy is assessed by shifting final demand from civilian to military uses, translating this demand into materials requirements, comparing these materials requirements to available supply (both new and recycled), and then estimating how long the current National Defense Stockpile will take the economy before it runs out. It is assumed that, during the crisis, prices will be high enough so that all capacity is used, and that construction times for expanding supply or diverting demand will be expedited as much as possible (even if current environmental strictures have to be waived for the duration).

For a detailed methodology consult Appendix B.

The analysis was conducted on two levels, for metal processing capability, and that for ore. Metal processing is likely to be a major constraint only as long as it takes to build more facilities; 18 to 24 months in emergencies. However, if capacity is deficient to begin with, then a stockpile which contains ores will not be usable. As for ores, if the basic resources do not exist within North America, no amount of construction will fix the problem. Only stockpiles and substitution will work.

Once analyzed, the metals examined can be grouped into three categories: non-problems, problems, and exotics. For non-problem metals, North American capacity already exceeds wartime demands by some margin. No stockpiles are needed to maintain the economy. For problem metals, most would require stocks before the economy was supported; in some cases demand can be manipulated so that the economy could survive a cutoff without requiring stocks. As for the exotic materials, much more needs to be known about their usage in war before appropriate stock levels can be determined.

A secondary purpose of this section is to estimate an appropriate size for the National Defense Stockpile for those metals and ores being analyzed. This estimate is made with the caveat that the assumptions used in this study are not those either mandated in law or used by prior stockpile calculations such as those conducted by FEMA in the late 1970's or the NSC in the early 1980's. Also as Appendix B and text below argue, a lot of work needs to be done to refine the current demand forecasting methodology. Of the 62 groups in the stockpile requirements (as defined by FEMA), only 33 are analyzed here. In prices as of 31 March 1986, they account for $8.7 billion of holdings of which $2.9 billion are in excess of requirements, and represent unfilled requirements of $8.3 billion. The other groups account for $1.3 billion in stocks, $0.1 billion of which are excess, and represent unfilled requirements of $1.3 billion.

Metals Which Are Not Problems: Metals for which the North American continent is well endowed with both ore or production capacity are iron and steel, copper, nickel, lead, zinc, antimony, bismuth, cadmium, silver, and vanadium. Two minerals, fluorspar and mercury, although not metals were also analyzed because of their industrial usage. Aluminum metal capacity is sufficient, but alumina and bauxite ore capacity is not.

Table 18 lists these materials, together with the following information on each: 1985 usage (in metric tons), wartime usage in proportion to peacetime usage, North American scenario demand (with fifteen percent added for Canada and Mexico), maximum recycling, North American capacity, and finally the ratio between supply and demand. The higher the ratio, the more adequate North American supply is relative to the war scenario demand. Ratios below 1.0 suggest that North American supply is inadequate in a war scenario.

Table 18

Supply-Demand for Non-Problem Metals
(data in thousand metric tons)

	1985 Demand	Wartime Ratio	Scenario* Demand	Recycling	Capacity	Ratio**
Vanadium	4.5	1.08	5.6	7.0	9.0	2.8
Zinc	1000	.70	800	100	1400	1.9
Iron Ore	56000	.96	62000	0	118000	1.9
Silver***	120	.85	120	25	190	1.8
Fluorspar	650	1.10	820	0	1300	1.6
Lead	1100	.98	1240	600	1300	1.5
Tungsten	6.0	1.10	7.6	0	10.4	1.4
Mercury****	54	1.00	62	10	76	1.4
Copper	2200	.95	2400	600	2550	1.3
Aluminum	5200	.95	5700	1000	5700	1.2
Steel	105000	.96	116000	0	130000	1.1
Bismuth	1.2	1.15	1.6	0	1.7	1.1
Cadmium	3.5	1.30	5.2	0	5.5	1.1
Nickel	200*****	1.37	315	65	250	1.0
Antimony	32	.80	29	18	11	1.0

* 1985 Demand x Wartime Ratio x 1.15 (for Canada, Mexico)
** Ratio = Recycling plus capacity divided by scenario demand
*** In million troy ounces
**** In thousand 76-lb. flasks
***** Includes the nickel content of imported stainless steel.

Those familiar with how war has boosted base metals demand in the past might be surprised that North American capacity is as adequate as it is. Those more familiar with how both the economy and military systems have evolved over the past few years will find fewer surprises.

North America's ability to supply base metals in war is largely adequate for three reasons. First, paying for increased military hardware requires a substantial decline in civilian hardware. Cars, for example, whose production would surely be curtailed in a major conflict, use considerable quantities of steel, aluminum, copper, lead and zinc; housing and related construction use steel, aluminum and copper in great quantities. Cutting back on both liberates a lot of supply for war.

Second, military systems no longer demand as many materials, per unit dollar, as they used to. This is largely due to the trend of packing individual platforms with as much capability as possible. This may mean more aggregate capability per dollar, but fewer platforms (and thus less material) per dollar. Twenty years ago, an F-4 was 98% aircraft and 2% black boxes by value. Today's F-18 is 57% aircraft and 43% black boxes. The same number of dollars buys less gross weight and more information. As for munitions, an attack on a bridge might have consumed $20,000 worth of iron bombs, weighing 10 tons; now it takes one laser-guided bomb costing $20,000 weighing half a ton.

Third, the materials intensity of the overall economy has, as noted, fallen sharply since 1973. Mining capacity, meanwhile, has adjusted to these market changes much more slowly. This has left considerable excess capacity in North America as well as overseas.

Also, materials for the same usage change over time. In the Korean War, tungsten supplies were very tight and the Federal Government created a large purchase guarantee to enlarge supply. Since then, the Army has adopted depleted uranium as its primary anti-armor penetrator and the requirements for tungsten in ammunition are now negligible.

These non-problem metals account for $2.2 billion of the National Defense Stockpile, $0.9 billion worth of which is excess to requirements, and generate un-met requirements of $4.6 billion.

None of this is to say that the United States will never have to worry about heavy metal supply again. Demands go up and down with changes in technology; supply adjusts with market conditions. If the continuing slump in metals prices leads to further capacity shutdowns, then more facilities will be taken out of production and what is currently stand-by capacity will prove increasingly hard to revive.

Metals Which Are Solvable Problems: Although the United States is currently dependent on overseas sources for rutile (one form of titanium ore) and the platinum group metals, it could get by without stocking them by demand management. Table 19 shows their current demand, scenario demand, shiftable demand, secondary supply and primary supply.

Rutile supplies can be stretched because rutile feeds both titanium metal plants (defense-heavy) and titanium pigment ones (commercial-heavy). The metal can only be made from rutile ore; the pigment can be made from rutile or ilmenite, the latter of which is abundant in North America. If pigment production is limited to plants which use ilmenite, rutile could be reserved in sufficient quantities for metal production. Meanwhile, because pigment demand declines in wartime, ilmenite-based pigment capacity alone should be able to meet demand.

Table 19

Supply-Demand for Solvable Problem Metals
(data in thousand ounces, except metric tons for rutile)

	1985 Demand	Scenario Demand	Shiftable Demand	Recycling	North Am. Capacity
Rutile	170,000	120,000	70,000	0	70,000
Platinum	1,200	900	500	150	320
Palladium	1,200	1,150	550	150	500
Iridium	11	16	2	2	12
Rhodium	93	17	40	11	25

Platinum-group supplies can be stretched by omitting the jewelry category outright, and cutting back on the production of catalytic convertors and high-octane gasolines during the war, as necessary. The dental usage of palladium can be substituted by gold, if need be, or by titanium. In addition, platinum-group inventories in private hands could accommodate a year's worth of essential demand.

The Stockpile holds $0.4 billion of these materials, and shows unfilled requirements of $0.6 billion for them as well.

Metals which are Problems: There will be some materials which would be hard to get in a war scenario in the absence of the National Defense Stockpile. Some are available in large part only from overseas: bauxite, chromium, cobalt, columbium, manganese, tantalum and tin. Others, titanium and beryllium, would be problems primarily because the military is currently a heavy user of such materials. Alumina and ferrochromium would be temporary problems, even though the US has some capacity, because many facilities have been closed recently.

Table 20 lists these metals, together with 1985 demand, wartime usage ratio, scenario demand, maximum recycling, initial (for the first 18 months) capacity and later capacity (months 19 through 48). Table 21 lists the early shortfall (first 18 months), the later shortfall (months 19 through 48), the size of the stockpile and the impacts. Impacts are shortfalls for certain metals, an estimate of excess stocks in the National Defense Stockpile or an estimate of rough balance otherwise.

Table 20

Supply-Demand for Problem Metals
(data in thousand metric tons)

	1985 Demand	Wartime Ratio	Scenario* Demand	Recycling	Capacity Early	Capacity Later
Beryllium	.27	1.85	.5	0	.37	.37
Manganese	620	1.25	900	0	300	650
Tin	50	1.00	58	13	6	6
Cobalt	7	1.65	13	.5	3	9
Titanium	18	2.80	50	0	28	50
Chromium ore	410**	1.05	495	90	0	30
Ferrochrome	300**	1.05	360	90	150	270
Tantalum	.5	1.80	1.0	.05	.15	.15
Bauxite***	4800	.95	5200	0	400	400
Columbium	3.4	1.30	5.1	0	2.2	2.2
Alumina***	4400	.95	4800	0	2900	3500

* 1985 Demand x Wartime Ratio x 1.15 (for Canada, Mexico) except 1.00 for beryllium and titanium.
** Includes the chromium content of imported stainless steel.
*** In terms of contained aluminum.

It should be noted that the US National Defense Stockpile will be assumed to cover the needs of Canada and Mexico as well. The fact is that Canada and Mexico have no stockpiles and, in an emergency, our willingness to supply their industrial needs with stockpiled material may be necessary before they are willing to supply our other industrial demands with primary material.

For chrome (both ore and metal), cobalt, tin, manganese and beryllium, North American capacity plus stockpiles is enough to get the economy through over three years of a wartime cutoff <u>without even taking the salutary effect of higher prices into account</u>. Of the rest, columbium and tantalum are real problems, the others, as discussed below, really are not.

Problems in the supply of alumina and bauxite would develop only if the US were somehow prevented from getting access to Jamaica and the southern Caribbean (Venezuela, Surinam, and Guyana). Access to those places will not be automatic; most of the first shiploads of bauxite to the United States in World War II were sunk. However, it should be possible to clear the Caribbean within a few months of war. Therefore, only a few months of stocks are needed and existing private stocks are at least that high now.

The main reason that titanium will not be a problem in practice is that between aircraft demand and titanium sponge production lies the nonferrous forgings industry whose capacity is at least as limiting and hard to expand as titanium is.

Table 21

Demand Versus Stockpile for Problem Metals
(data in thousand metric tons of contained metal)

	Shortfall Early	Shortfall Later	Stockpile	Impact
Beryllium	.20	.35	1.2	$ 120M surplus
Manganese	900	600	1700	$ 50M surplus
Tin	58	48*	181	$ 1000M surplus
Cobalt	14	9	24	adequate stocks
Titanium	33	--	24	12% shortfall thru month 18
Ferrochrome	180	--	550	see text
Chromium ore	610	940	650	75% shortfall after month 37
Tantalum	1.2	2.0	.9	80% shortfall after month 15
Bauxite	7000	12000	3600	90% shortfall after month 8
Columbium	4.5	7.2	.8	55% shortfall after month 3
Alumina**	2400	--	0	30% shortfall thru month 24

* Reflects reduction of 20,000 tons/year after month 18; see text.
** Reflects 600,000 tons of revived capacity after 6 months and unlimited new capacity after 24 months.

Tantalum and columbium may present real problems in war. Both are used disproportionately in aerospace and stocks of both are roughly a year's worth of necessary imports. Of the two, tantalum is the more vulnerable. The United States would have to go to Africa or Southeast Asia to meet demand. By contrast, most of the world's columbium can be acquired from Brazil, a more accessible source. Besides what is shown in Table 21, the National Defense Stockpile holds columbium and tantalum in non-stockpile grades. If upgraded they could fill another two months of the columbium shortfall and seven months of the tantalum shortfall. To fill the shortfall with additional stocks would require 24 million lbs. of columbium ($150 million) and 5 million lbs. of tantalum ($140 million).

Relative to the capacity which can be generated in emergencies--both for mining and smelting--the Stockpile has too much metal and not enough ore (to last four years). The value of the surplus metal is roughly $400 million. To replace the ore content of the metal and cover requirements out through four years would require $300 million. As it is the General Services Administration (GSA) is buying metal to help the domestic ferroalloy industry stay afloat. Follow-on capacity for both chromium and cobalt already assumes the reopening of mines closed for essentially thirty years as well as the restart of ferrochromium plants currently idled.

Tin stocks appear to be ample. Since roughly 30% of all virgin tin is used in tin cans, conversions to glass and aluminum containers could probably stretch supplies. It would take 18 to 24 months to complete such conversions, however. What supply exists on this continent reflects considerable recycling and a new mine in Nova Scotia (whose ores are currently to be smelted overseas).

Manganese supplies appear in good a shape because some heroic capacity expansion measures were assumed. Such expansion would reach 800,000 tons of contained manganese, prompted by prices as high as ten times current rates. This increase is several times that experienced in the Korean Conflict. Without this new supply, the stockpile has only three years of material.

With beryllium, ore stocks are more than sufficient to carry production through and metal capacity should be adequate for wartime usage as well. If the current producer is forced to close because of environmental problems, this situation would change drastically.

An alternate scenario which assumes that North, Central, and South America are accessible to each other but not anyone else, improves the situation for six of the minerals dramatically. The ratio of capacity to scenario demand for the Americas is 2.8 for columbium, 1.2 for alumina and beryl ore, 1.1 for bauxite and manganese and 1.0 for tin ore. Smelting capacity in the Americas for tin, however, is short by 10,000 tons.

The Stockpile holds $6.2 billion worth of these materials, of which $1.8 billion (tin) is surplus to requirements. Meanwhile, $2.8 worth of unfilled requirements remain. Alumina and bauxite aside, this study suggests that roughly $1.2 billion of these materials could be sold outright. Another $400 million of ferrochromium could be traded for $300 million in chrome ore, and $300 million worth of columbium and tantalum could be purchased. As for alumina and bauxite, the strict assumption of no North American imports could create a requirement for a billion dollars worth of alumina and three billion dollars worth of bauxite. As noted above, both exceed plausible needs.

Exotic Metals: Advances in military systems technology have created concerns that the United States may be unable to procure key high-technology metals, previously considered important. Five metals--germanium, gallium, indium, scandium and selenium-- were looked at in order to estimate their stockpile requirements. As discussed below all five, unfortunately, need more work before their requirements can be confidently assessed. In any cases the numbers are not large. The total domestic usage of germanium dioxide is roughly $25 million; for the other four combined, $20 million.

Germanium, an expensive metal ($600,000/ton), is mostly used to build infrared optical systems, such as FLIR (forward-looking infrared) pods on aircraft. In 1984 FEMA and the NSC determined that germanium was a strategic and critical material. A goal of 30 metric tons was established (the NSC seeks 146 tons) with an FY 87 purchase planned. Current usage is roughly 38 tons, but with two thirds being military, wartime usage could rise to 110 tons. (If current demand is based on platform retrofit, it will not rise in proportion to new platform production, however.) Capacity is roughly 40 tons in North America. Completion of the Red Dog Mine in western Alaska (1991?) could raise capacity to 100 tons. Unfortunately, access to this mine requires a transit of the Bering Strait, blocked by ice most months of the year (and Soviet submarines the rest?). More work is needed on projected military demand, access to western Alaska, and prospects for emergency substitutability.

Gallium is used to make gallium arsenide (GaAs) semiconductors, a possible successor to silicon semiconductors in many important applications. At present, the military is the largest user of GaAs, and, as such, demand would be expected to rise from its current levels of 7 tons in 1985 and 15 tons in 1986. Domestic supply capacity should reach 9 tons within a few years. The direction of the GaAs market is hard to gauge. The technology has been described as having had "a wonderful future." Greater usage of GaAs chips over time also does not necessarily mean higher gallium consumption if the yield of good chips from wafers rises with production experience. Another question is the usefulness of stockpiling gallium when the United States is dependent on Japan for GaAs transistors and much of its substrate.

Indium is used in electronics, optics, and cryogenics. Currently, military use runs roughly 10 to 15 percent of total demand. Perhaps 20 to 50 percent of the raw residues processed by US refiners are imported. Current North American refining capacity, 1.4 million ounces, appears adequate to meet the 700,000 ounces of consumption. More work is needed on where refiners are getting their ore before stockpile goals can be determined.

Samarium is a rare-earth used in magnets associated with, among other things, aerospace actuators. Current military demand is estimated to be anywhere from 10 to 25 percent of total demand. Meanwhile domestic production capability is 90 tons compared to total domestic demand of 100 to 150 tons.

Scandium can be used to build blue-green lasers, of potential use in strategic applications such as the Strategic Defense

Initiative (SDI) and submarine communication. Military use is estimated at 50 kilograms a year; commercial use (mercury vapor lamps) at 20. One mine, operating in 1985 but since closed, had the capacity to meet the combined 70 kilogram demand. As with gallium, it is not yet clear how scandium demand will shake out, particularly since blue-green lasers have no demonstrated long-term market, yet.

Comparison with the NSC Study Results: The primary conclusion of the NSC study was that the current stockpile is grossly overbuilt. True requirements would be no more than $700 million dollars worth of materials ($600 million worth of those materials analyzed above).

Compared to NSC's work, this study assumed a conflict roughly twice as large, a GNP roughly fifteen percent larger, a four-year conflict with no warning time (rather than a three-year conflict with a year's warning time), and that all supply for military, industrial, and civilian needs had to be met from the North American continent. In many cases these are stiffer assumptions than those made in previous studies. As such this study's results are highly conservative (biased upwards).

It is difficult to present a more detailed comparison with the NSC results because of the classified nature of many of its calculations and the inherent difficulty of penetrating such a large model to play "what-if" games. The General Accounting Office (GAO), by making several more-or-less plausible changes in the assumptions, determined that one could calculate a stockpile goal of $8 billion dollars as easily.[16]

A Southern Africa Excursion: A cutoff from southern Africa and COMECON countries may be a more likely consequence of war than a complete cutoff of North America from everywhere else. Table 22 contains estimates for southern African capacity, and for demand and capacity for the world outside COMECON and southern Africa, together with the ratios between them. Eight minerals are covered; those for which southern Africa provides at least 10 percent of the world's capacity.

Only four of these minerals would be short--that is, would require stockpile dispersals--if southern Africa were unavailable. The United States supply situation would be better for cobalt and chromium compared to the war scenario (in which North America was completely cut off). For manganese the US would do worse in a southern Africa excursion than it would if the Western Hemisphere were isolated, but better than if North American alone

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16. The General Accounting Office, National Defense Stockpile: National Security Council Study Inadequate To Set Stockpile Goals, May 1987, GAO/NSIAD-87-146.

were isolated. For platinum-group metals, the US position is best if North America were cut off, and worse if North America had to share resources with the rest of the world following a cutoff from southern Africa. However, as noted, the platinum-group metals are among the easiest to substitute away from.

Table 22

The Impact of a Southern Africa and COMECON Cutoff
(figures in thousands of metric tons)

	CAPACITY S. Africa	ROW*	ROW Demand	RATIO
Antimony	20	65	42	1.5
Vanadium	17	28	21	1.3
Copper	2300	6100	6000	1.0
Fluorspar	700	3800	3700	1.0
Manganese**	4200	4200	6200	.7
Cobalt	11	6	11	.5
Chromium**	1600	1000	2100	.5
Platinum-group***	4100	800	6600	.1

* Rest-of-the-world excluding southern Africa and COMECON
** contained metal
*** thousands of troy ounces

Conclusions

Energy: At least until the price of oil dropped in 1986, the United States could withstand an extended overseas oil cutoff without major damage to the economy under wartime conditions (assuming that the United States had preferential access to Canada and Mexico). Scenarios in which oil-rich parts of the world are cut off and the entire developed world finds itself energy-short may pose greater problems for North America than a complete cutoff.

What allows the United States to withstand a complete cutoff is the presence of excess capacity for both natural gas and electricity. This, combined with the impact of shifting demands in the economy, allows all demands except for motor gasoline and jet fuel to be met. They would have to be restricted.

Since the collapse in oil prices in 1986, this position has become less tenable. The first reaction was a sharp fall in oil production here; the second will be a deceleration and perhaps reversal of conservation trends. By the early 1990s, if oil price declines continue, it may not be possible to withstand an oil shortfall by modest reductions in motor fuels.

Metals: In general, metals and related materials will not be among the major problems in gearing industry to war, even in the event of a complete foreign source cutoff. The National Defense Stockpile is sufficiently large in most cases to cover several years' worth of import requirements. The most prominent shortfalls are in the area of columbium and tantalum, but the former comes from Brazil and the latter would not cost much to fix. In addition, some encouragement for aluminum companies to hold additional alumina stocks may be prudent to buy the time necessary to ensure the Caribbean in a major war. Stockpile requirements, if any, for exotic metals need more work concerning military demands; in any case, total quantities are small.

So, Why Isn't The US More Vulnerable?

The relative invulnerability of the North American continent may be contrasted against the degree of import dependence commonly portrayed. This situation appears more dire when the large material requirements of defense are added on top. Yet, the difference may be explained as follows:

- A large percentage of our imports comes from Canada and Mexico, both of which may be considered accessible sources in a crisis.

- The United States Government has been aware of the problem for a very long time, and has bought a considerable inventory of materials to cover just this contingency.

- A good share of the increase in imports has been associated with a declining utilization of our mining and processing capacity; the latter is still around (or revivable) to be used in emergencies.

- Meanwhile, over time the economy generates ever more output with fewer materials.

- Finally, Defense spending per se does not raise the demand for materials in a vacuum. Buying more war goods means buying less of something else and, except for a few exotic materials, it takes fewer materials to make war goods than the something else.

SECTION FIVE

Case Study Of A Potential Technology Dependence: Integrated Circuits (ICs)

Introduction: The United States fields fewer forces than its adversaries. It thus has chosen to rely on maximizing the performance of its systems. Unfavorable numerical balances mean that we have to believe that the superiority of each of our weapons counteracts our adversaries' greater numbers.

The quality of performance depends on many characteristics. Among these are communication, target acquisition and detection, sensing and tracking, and damage assessment. Fundamental to any of these are the electronics that such systems contain. This is often held to be the key factor in differentiating our weapons from the Soviets'. The growing importance of electronics can be illustrated by the F-18, the plane which is rapidly replacing the F-4 in the Navy's arsenal. The former is 43% electronics; the latter, 2%. To quote the Economist,[17] "The miniaturization of electronics has been by far the most significant military development of the past two decades."

Electronics capabilities are increasingly represented by the performance of embedded integrated circuits (ICs). Fears have been raised, however, that the United States may become dependent on Japan for many of the ICs which form the brains of our high-technology weaponry. Should this occur, US systems designers would have to choose between using a second-best technology or going abroad for their ICs. The latter introduces the possibility of increased leverage by Japan over our political decisions, the denial of certain technologies, or, at very least, a greater lag before the best technologies work their way into US weapons systems (and perhaps a smaller lag before they appear in Soviet systems).

This threat has been cited in support of calls for Government assistance, in a variety of forms, to this vital sector. They range from trade protection to additional R&D funding and participation in new production facilities. Both the Defense Science Board and the National Security Council, among others, have given this problem serious attention.

The context of technological dependence differs from those of physical dependence discussed in the case studies on PGMs or industrial materials. Clearly, a technological dependence may give rise in the future to a physical dependence. But many people are concerned over ICs who do not consider physical

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17. Economist, 21 May 1983, p. 3.

dependence in a wartime context to be plausible in and of itself. Technology dependence may be said to have a subtle but pervasive effect on America's ability to access the world's best technology. And because advances in IC functionality are key to improving the quality of weapons, lack of access to such advances matters.

The logic of national security which calls for assistance to the IC industry can be boiled down to four theses. The first holds that the domestic industry is declining so irreversibly that future producers will be relegated to isolated niches. Second, the decline of the commercial industry will make it difficult for DoD to get leading-edge ICs without buying overseas. Third, buying abroad, in and of itself, will limit DoD's access to leading-edge technology for a variety of reasons. Finally, however, DoD can do something cost-effective to help the industry and so preserve its access via domestic sources.

The Defense Science Board makes a seven-fold case:

- DoD depends heavily on technological superiority to win.
- Electronics is the technology that can be leveraged best.
- Semiconductors are key to electronics leadership.
- Semiconductor leadership requires high competitive volumes.
- High-volume production is supported by commercial work.
- Leadership in commercial volume production is being lost.
- Semiconductor technology leadership will soon move abroad.

Of greater import is the gut fear behind the facts. It concerns the future of US technological superiority vis-a-vis others, Japan as much as the Soviet Union. Our military contest with the Soviets is said to be only different in degree from our economic contest with the Japanese. Being less than number one leaves us vulnerable to forces beyond our shores, a dangerous situation whether or not the other country is our declared ally or adversary. Insofar as the IC industry is technology's cutting edge, anything that can be done to reinstate our number one position makes the United States better off.

The problem also admits an alternative point of view. The Japanese have created technological capabilities that our market can take advantage of. If the market alone mediates the terms on which we deal with Japanese industry, we get one pattern of consequences. If some strategic thinking can be brought to our industrial capabilities and their relationship with those of the Japanese (among others), outcomes more favorable to national and/or economic security are possible.

Background

Integrated circuits (ICs) are the largest subset--80% by value--of a group of electronic components called semiconductors. Other semiconductors, such as transistors, thyristors and diodes, are also important and the US is highly dependent on Japan for these. However, their design characteristics are not so important to system architecture and they are not the focus of the key studies on the topic.

Integrated circuits are important because they contain many (approaching one million) logic elements which allow them to perform many computational and storage functions hitherto found only in complete computers.

ICs start life as wafers, round disks usually of silicon repeatedly imprinted with a identical electrical circuits. This wafer is cut up into hundreds or thousands of individual pieces. The good ones are packaged, generally, into flat cases with leads sticking out the bottom, a process most often done overseas, usually in Southeast Asia. References to where ICs are produced, however, refer to wafer fabrication.

Almost 80% of the free world's ICs are built by US or Japanese companies. Western Europe, although active in the market, runs a weak third. Except for upcoming Korea and Taiwan, there are no other volume competitors.

The US IC industry is a melange of large merchant producers, small niche producers (also merchants), and in-house suppliers (captives) to large companies. Seven producers--Intel, National, American Micro Devices (AMD), Motorola, Texas Instruments (TI), General Electric (GE), and Signetics--account for half of the US base. These are full-service producers with products that span a wide range of functions. Among them, Intel, National and AMD derive most of their revenues from semiconductors and are most subject to major market fluctuations. Motorola and TI get roughly a third of their revenues from semiconductors and are only partially affected by fluctuations. GE's ICs are only 1% of the company; Signetics is only 3% of Philips (a huge European multinational).

The niche producers, accounting for 20% of the US base, build only selected items. Starting from Harris, and working downward in sales volume, they include new start-ups, such as VLSI and LSI Logic (both producing application-specific ICs), as well as old start-ups that stopped growing, and small sections of larger producers (particularly aerospace).

Captive producers build ICs only for their own use. IBM alone accounts for over 60% of the production by captives. AT&T,

the next largest producer, accounts for roughly 15%. Others include GM (Delco) and a number of mid-size computer companies.

By contrast, the Japanese sector is dominated by six similar vertically integrated firms; Fujitsu, NEC, Hitachi, Toshiba, Mitsubishi, and Oki. Each is an integrated electronics company producing a wide variety of end-items, using roughly 20% of their own ICs and selling roughly 40% to the other five large companies, 20% to other Japanese users and the last 20% to overseas users.

One key difference between the US industry and the Japanese industry is the composition of demand. Almost half of the ICs made in Japan go into consumer electronics; computers and capital goods make up the rest. The US has almost no consumer electronics sector; here computers are more prominent. So is the military sector, accounting for 9% of the US industry's sales (4% by volume).

Trends

The Bad News: Only three years ago, the IC industry was being hailed for its robust entrepreneurship and exemplification of the free market's energy (qua George Gilder). Now it seems to be just one more petitioner for trade protection.

Table 23 illustrates the roller-coaster nature of the IC market and the context for today's concern.

The high growth rates experienced in 1983 and 1984 encouraged US producers to add capacity in like proportions. The next year, however, sales fell sharply rather than rising, and recovered only slightly in 1986. The merchant industry, collectively, has lost roughly a billion dollars over the last two years as price-cutting affected revenues for a wide variety of products. Overseas, the Japanese have also taken losses but have nevertheless managed to maintain R&D expenditures and capture market share. At some point in 1986, the Japanese IC industry began to exceed the American merchant industry in size. In part this was to currency movements, but there is little doubt that the basic trends will continue.

Similar declines can be observed in the world shares of US semiconductor equipment producers, from 80-90% ten years ago to 60-70% today. US producers were once supreme in all areas. It is now acknowledged that Japanese products are on the cutting edge of at least three categories: optical steppers, rapid testers, and e-beam lithography devices.

Table 23

IC Production By Region*
(in $ billion)

	1976	1980	1982	1983	1984	1985	1986
US - merchant	2.2	6.4	6.2	7.9	12.3	9.3	9.8
- captive	0.6	3.0	3.4	3.8	4.6	4.8	4.9
JAPAN	0.6	2.3	3.0	4.4	7.8	7.1	9.6
EUROPE	0.3	0.7	0.8	1.0	1.6	1.5	1.8
OTHER	0.0	0.1	0.2	0.2	0.4	0.4	0.7
TOTAL	3.7	12.5	13.6	17.3	26.7	23.1	26.8
US/TOTAL (%)	76	75	71	68	63	61	55

* By location of headquarters-firm. IBM, Europe is counted as US, NEC, California is counted as Japan. US producers in Japan and Japanese producers in the US each account for one percent of the world's volume.

SOURCE: Integrated Circuit Engineering Corp (ICE)

With the decline in its world market share came a comparable switch in the relative ranking of world firms. As Table 24 shows, for instance, 8 1/2 of the world's top 10 firms were American ten years ago (the half is Philips-Signetics). Now only 5 1/2 are and by 1991 only 2, IBM and Texas Instruments, are projected by ICE to be. Six will be Japanese, one Korean and one German.

Table 24

NUMBER OF US PRODUCERS AMONG WORLD'S TOP TEN IC MAKERS

Year	1976	1982	1984	1985	1986E	1991P
Number	8.5	6.5	6.5	5.5	5.5	2.0

Source: ICE

Several individual analysts, Tim Stone (previously CIA's chief industrial competition analyst) and Charles Furgeson (MIT) have been even more gloomy. The latter expects that, by 1991, the major merchant producers will have either gone broke or been sold to Japanese firms. A harbinger of the latter was the Fujitsu's attempted purchase of Fairchild Semiconductor, the original fount of Silicon Valley. This followed the purchase of Mostek by Thomson, a French electronics firm (in both cases, however, the firms sold were independent subsidiaries of conglomerates with alternative business thrusts). Japanese companies, as of late, have also been buying into many IC-related start-ups in the United States.

The most obvious indicator of Japanese market penetration has been for dynamic random access memories (DRAM), a $4 billion market (worldwide). Table 25 charts their progress.

Table 25

Japanese Share of the World DRAM Market

1970	1K	0%
1974	4K	5%
1978	16K	40%
1982	64K	70%
1985	256K	85%
1987	1M	90+%

Source: C. Furgeson (from Dataquest, Hambrecht & Quist, SIA)

The ascendancy of Japanese firms in markets is also echoed by their relative improvement in technology. The CIA compared Japanese to United States technology in twenty cases and found that the Japanese were ahead in nine, at parity in eight, and behind in only three. In fourteen cases they were gaining on US firms; in no case were they falling behind. The National Academy of Sciences reported that Japanese were ahead in seven of the ten key electronics materials technologies. Another indicator has been their performance at scientific conferences, most notably the annual International Solid-State Circuits Conference (ISSCC), as shown in Table 26.

Table 26

Accepted Conference Papers At Annual ISSCC Meetings
Distribution by Region

Year	1977	1985	1986	1987
Japan	16%	45%	43%	40%
United States	76%	38%	48%	48%

Source: Tim Stone (CIA), Electronics.

As one journal, Electronics, observed in late 1986:

> . . . for researchers in the United States, next year will serve up a good-size portion of humble pie. Regardless of how firmly they believe in their continued technological leadership they are going to have to be reminded again that the Japanese are close to snatching that crown, at least insofar as participation in professional conferences such as the ISSCC is concerned. The Japanese have 40 papers (up from 35 last year) versus 48 for the Americans. And in almost every session, except those relating to analog circuitry and microprocessors, Japanese papers dominate in terms of quality.[18]

These data yield a very pessimistic view of the industry's plight. The caricature shows a monolithic Japanese industry, at first borrowing U. S. technology and then using what it borrowed, combined with cheap capital, to launch price wars in selected IC memory products: first DRAMs, then static memories (SRAMs) and now threatening CMOS gate arrays. This onslaught, having depleted the US industry, prevents the merchant producers from financing the capital or the research for the next generation of products. The result is that domestic firms fall further behind, and become prey for Japanese control.

Signs of Survival: The data also support other, and possibly more valid, explanations. First, what many data indicate is not the deteriorating performance of the US IC industry but the technological momentum of the Japanese one. DRAMs are one example. From 1965 to 1979, while US firms dominated the industry, each successive fourfold increase in memory, from 16 bit, to 64 bit, 256 bit, 1K, 4K and 16K took roughly 2.8 years to reach the market in a steady progression. Thereafter, the Japanese took the lead in introducing DRAMs and spawned three generations in the subsequent seven years, or 2.3 years per cycle. The old pattern would have lagged 1.5 years (3 x [2.8-2.3]) behind. This is about the extent to which US producers are behind the Japanese, a sign that US producers collectively maintained the same cycle speed, while the Japanese cycled faster.

Japanese production has also grown more quickly because its internal markets have. As table 27 indicates, the ratio between internal markets and IC production has changed little over the last few years for both Japanese and domestic production. The key difference is that the Japanese surplus over their market is reflected in their exports from Japan, and our producers setting up wafer fabrication facilities down-market.

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18. Electronics, 27 November 1986.

Market shifts also influence the composition of IC production flows. High-definition TV is slated to take 40% of the next generation DRAM chip (1M). Without a consumer electronics industry, the motivation for US producers to produce such a product is correspondingly reduced.

Table 27

Ratio Of Japan, US-Based Sales To Total Internal Market Size

Year	Japan	United States
1982	1.1	1.3
1983	1.1	1.2
1984	1.2	1.2
1985	1.2	1.3
1986	1.2	1.3

Source: ICE

The same story can be observed in trade flows. Table 28 indicates that Japanese firms have roughly the same share of the US market that US firms have of the Japanese markets, with only minor changes over the last four years. This is in contrast to almost every other industry where the super-dollar has led to a higher import share in American markets and a lower export share in overseas ones. In Western Europe, neutral ground between the US and Japan, native producers hold half of the market: US firms (mostly through their subsidiaries) hold a third and Japanese hold a sixth.

Table 28

US Imports/Exports Of ICS To Japan
(in $ million)

Year	Imports	(% of mkt*)	Exports	(% of mkt**)
1982	450	6	290	11
1983	750	8	410	10
1984	1585	11	700	11
1985	880	8	500	9
1986	1050	9	700	9

* includes U. S. captives
** Japanese market

Source: ICE

Similarly, the declining shares of US-based semiconductor equipment producers in the world market reflect the growth in Japanese demand for equipment coupled with the increasing share of Japanese equipment producers within their own market.

The rising presence of Japanese firms in the roster of the world's top ten producers can be explained in part by their higher concentration ratios. Assets in Japan are concentrated in a few firms. In the United States they are spread out. Table 29 indicates that the largest four producers in Japan control two thirds of the total production; the top four in the United States, less than a half. To reach 80% of Japan's industry, six firms are enough; in the United States one needs fourteen firms.

Table 29

Concentration Ratios For IC Production

Concentration Ratios	Japan	North America
Largest 4	66%	48%
Largest 8	85%	67%
Minimum Producers to Reach		
50% of total sales	3	5
80% of total sales	6	14
90% of total sales	9	25

Source: ICE

As for technological trends, the Japanese ascendancy in memory ICs is not disputed, but in other areas, such as micro-processors, the Japanese have failed to grab a foothold (except by licensing or copying US designs). Graphics processors, once the exclusive domain of NEC and Hitachi, are finding strong competition in chips developed by Intel, TI and NCR. US firms still claim international leadership in linear circuits, digital signal processors, and programmable logic and memory devices.

Comparing technologies and markets in new areas, the Japanese are clearly ahead of the merchant producers in opto-electronic devices; in the US, however, Bell Labs is on the cutting edge. The growth potential in optoelectronics is still in the future. Extrapolating from the last two years (from Electronics), it would take 15 years for the market share of optoelectronic ICs to double relative to all ICs.

Other growth areas include ASICs (application-specific ICs) and gallium arsenide (GaAs). ICE forecasts the world ASIC market to grow by over 25% a year. US firms now hold 71% of the world market (50% in gate arrays, 95% in standard cells, and 64% in logic-programmable devices) against 17% for the Japanese, and 11% for the Europeans. ICE projects the US share in 1991 to stay high; 57% of the market against 25% for the Japanese and 14% for the Europeans.

In GaAs, the Japanese are considered to hold a large edge in the fabrication of raw material and in the production of GaAs transistors. (The products they replace, silicon field effect transistors, are also dominated by Japanese producers now.) In GaAs integrated circuits, however, as ICE data notes, the top five sales leaders are US firms, and the US market itself represents 81% of the total world market. (71% of the world GaAs market is captive.)

Overall, the Japanese appear ahead in the race to develop finer geometries (e.g. lines/circuits per unit area), driven by their DRAM work. The US, for its part, has innovative designs not yet matched overseas. The Japanese are also ahead in a second-generation GaAs technology, high-electronic mobility transistors (HEMT), but not in other competing designs (MODFETs). Their next-generation etching technologies (E-beam, X-ray etc.) are also better; so too is their three-dimensional IC research.

Implications: One explanation, Charles Furgeson's, of the industry's problems is that the industry's structure has hurt its transition from the LSI (large-scale-integration) era to the VLSI (very large-scale-integration) era. The scale-up in technology was associated with a shift in the minimum economic plant from a $20M investment in the 1970s to a $200M investment in the 1980s. US firms, generally smaller, and independent, have been unable to finance that transition. Japanese firms, most of which are owned by much larger electronics firms, could and did. If this is the case, public policy should tilt against the proliferation of start-ups which have hitherto characterized Silicon Valley and tilt towards some industry-wide consolidation.

The data suggest, however, that it is not the US firms which have become worse over the years, so much as it was the Japanese which, having come from behind, have developed momentum. Even so, US firms have managed to hold their own in the three major markets (US, Japan and Europe). World production share shifts have primarily reflected whose customers are growing fastest and not relative production prowess per se. The policy implications of the "deep-pockets" theory are also not obviously useful. And, according to George Heilmeier, VP of TI, the discouragement of industry start-ups at the opening of the VLSI era would have deprived the US of its current position in ASICs.

The transition from VLSI to ULSI (ultra large-scale integration) is unlikely to lead to a corresponding scale-up in capital intensity. According the ICE, the capital/output ratio increased from $.45 in the mid-1970s to $1.61 today (14%/year). Over the next ten years the ratio is only expected to grow to $1.72 (1%/year).

Real Problems in the IC Industry: The problems of the domestic IC industry, and they are real, differ from those commonly cited. Key among them are its vulnerability to business cycles and their consequent tendency to discount the future more than is good for it or for national security.

The most salient fact of the IC industry over the last two years (1985-1986) has been its loss of over a billion dollars in the face of excess capacity. Capacity had been installed in response to the 1983-84 market boom, itself a reflection of similar increases in computers (especially microcomputers). But much of the boom was illusory, a result of customers ordering for inventory because they had trouble getting chips (because the industry had cut back investment in the previous recession). Inventory rose from a normal 8 to 12 weeks. When the boom died, excess capacity appeared, lead times shrank and customers reduced inventories below normal, down to 4 weeks. The result was an exacerbated boom-bust cycle. By one estimate $1.0-1.5 billion of the chip demand in 1984 was for stock building. Subsequent drawdowns of stock reduced sales by twice as much. Without this behavior sales would have risen at a slower pace in 1984 and maintained their level over the next two years.

The Japanese were less affected by this cycle because their main market, consumer electronics, grew more predictably. Also, the intercorporate connections between IC houses and their customers protected them from the overstocking/understocking that whipsawed US merchants. In general, Japanese firms managed to maintain a more stable capacity utilization rate. What the US cycle did hurt was exports to the US. Contrary to popular impression, direct imports from Japan have not been the primary cause of the weak order books of domestic IC producers, although price wars instigated by imports hurt domestic revenues from certain memory products.

One reason that imports have been able to make the inroads they have is that the investment patterns of US firms are highly cyclical. Japanese firms were able to make large inroads in 1980-81 as well as 1983-84 because US firms, not having invested in capacity at the right time, were unable to satisfy customers. Once entrenched in the market they have been able to hang on to their newly won shares (this phenomenon, which also appeared in the cement and steel industry, is not unique to ICs).

The other key difference is a matter of attitude and expectations about the future. Integrated Japanese firms view their IC operations, in part, as supporting the technological advances necessary to promote their electronics production. They appear more willing to take low profits in order to gain the competitive edge that having proprietary production capability lends to their electronics businesses as a whole. But as the president of ICE remarked,

> . . . [US firms] follow the typical American strategy of trying to keep the semiconductor units responsible for their own profits and losses.[19]

Integration matters because it allows firms to capture the technological synergies between ICs and products. It is significant that both IBM and AT&T, the first two US companies to produce 1 megabit dynamic random access memories (1M DRAMs), are also in a position to factor this kind of competitive edge in their calculus. Below a certain threshold the independents lack this factor. (Motorola and TI, which most resemble the Japanese firms, use only 10% of their own ICs).

The environment of instability also prejudices many American companies away from long-term technology strategy in general. An illustration of this difference may be gleaned from comparing Japanese and American attitudes on new technologies such as "smart-cards" (e.g. bank cards with memory and logic capabilities). According to Sheridan Tatsuno (Dataquest):

> The US has been slow on its feet. The American firms say, 'There is no market here; why waste our time?' Japanese say 'There will be no market for five years, there is time to do the groundwork.'[20]

The differences are becoming evident in each country's reaction to the current downturn. Both American and Japanese firms each lost a billion dollars in 1985-1986, and both have maintained or even increased their R&D spending. The nature of this R&D differs, however. American companies tend to measure their R&D by the ratio of dollars spent to products produced (that year or the next). The Japanese seem to take a longer-term view towards developing technologies that might not be commercial until several years later. The Japanese share of sales going into research, while always higher, is now significantly so. One visible result has been the recent construction in Japan of dozens of new laboratories dedicated solely to semiconductor R&D. Some of this reflects strong support by Japan's Ministry of

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19. Electronics, 13 November, 1986.

20. Electronics, 18 December 1986, p. 56.

International Trade and Industry (MITI): some reflects support by Japan's phone company (NT&T). Most is financed by the corporate parents of Japan's IC firms.

The dominance of environmental conditions over cultural ones in explaining the short-term emphasis of American's corporations may be indicated by the counter examples of companies such as IBM, Digital Equipment Corporation (DEC), and Hewitt Packard (HP). America's university research in technologies is also considered to be much more long-term oriented than that of Japan, which is more closely tied to commercially practicable ideas.

There is also a distinction between Japan's focus on incremental improvements versus America's focus on conceptual breakthroughs. To quote Hajime Sasaki, the NEC's Vice President for Electron Devices:

> The semiconductor business can be roughly divided into architecture-design technology and wafer-processing and device-structure [know-how] . . . the US strengths lie in the architecture while Japanese strengths are in the wafer design and processing.[21]

and, in addition, to quote executives at Convex Corp.:

> The Japanese companies seem to be very good at exporting the raw resources--nuts and bolts of computer technology, if you will--but they have had difficulties bridging the gap to implement systems in the systems market.[22]

Which is more important? To compete requires knowing both. A growing advantage in production would allow the Japanese to capture markets that once went to American firms because of their design innovations.

One result is to leave the Japanese producers, less affected by business cycles, in a better position to face the future. As noted above, American firms expect their semiconductor operations to be their own profit center. Japanese firms, more integrated and generally better financed, do not. While this fact per se lends more cost discipline to American operations it also puts them at the mercy of short-term trends.

Trends: The easy prediction is that the industry will change in major ways: the hard prediction is how much and where.

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21. Electronics, 18 December 1986, p. 33.

22. Electronics, 30 October 1986, p. 59.

Chips will still be getting denser, faster, and cheaper (and probably larger). Circuits per unit area and per dollar, increasing at 20% a year, show no sign of slowing down. However, sales growth, while likely to resume, is unlikely to repeat the torrid performance of the early 1980s. Most of the substitution possibilities (e.g. against electromechanical devices) have already taken place. Increases in per-unit capability will be largely counteracted by decreasing unit prices.

Application-specific integrated circuits (ASICs) will account for an increasing share of the market. An ASIC, in essence, requires that the customer participate actively in the design process. This represents a shift in expertise and value-added away from the maker to the buyer.

Software design will become an increasing percentage of the cost of chip production. This will, to a large extent, counteract the increasing competence of Japanese manufacturers vis-a-vis American ones, by making production considerations of decreasing importance. One harbinger of an implication of this trend is an IC being developed by TRW (for DoD) in which deliberate design redundancies are engineered which could keep the chip running in the presence of multiple defective parts. Another implication, however, could be the creation of transnational partnerships designing here and producing in Japan.

Merchant IC houses will survive. The industry is too large, too diversified, too important to domestic customers, and, yes, too competitive to disappear entirely. New product introductions are still the chief driver as far as generating sales are concerned and there is no evidence that the pace of new designs from domestic companies is slowing down. However, it is likely that the large merchants will account for a smaller share of the total industry. This is particularly evident from the various steps that the major merchants are currently taking to specialize their offerings and downsize operations to a profitable core.

Developing the right strategic relationships will be an increasingly important determinant of survival. One recent trend is toward relationships between individual customers and producers: IBM-Intel, AMD-Sony, National-Xerox. Another trend is towards linkups with overseas companies via purchase by stronger of weaker (as Fujitsu attempted for Fairchild) or a partnership of equals (Motorola-Toshiba). Linkups are proceeding at such an accelerated rate that, as far as technology is concerned, the borders between corporations, much less their home nations, are becoming increasingly difficult to define.

There will be no shortage of start-ups, although the pace may slacken from peak years of the past. Unlike start-ups from then, many will be looking for someone else to do their manufacturing while the company is in its early growth period.

An increasing percentage of the production value-added for certain technologies will be performed in low-wage areas (much as IC assembly is now relegated). US firms, in such arrangements, will maintain their overall design, marketing, systems integration and management roles.

Those are the easy predictions. The hard one has to do with the extent to which domestic companies are willing or able to stay on the cutting edge of the technology as it descends to finer and finer geometries. If they can do so, there is little doubt that they can keep most of the domestic market and retain export markets, regardless of other factors. Otherwise, they will increasingly be relegated to niche markets, and software, design, and integration functions for which the manufacturing is done overseas.

None of this should imply that the Japanese predilection for large facilities is a panacea. In many cases the trend seems to be running the other way. MITI is now admitting that the number of 6-inch wafer lines is excessive, and it seeks to restrain or close down a number of those deemed superfluous. A related trend is towards the construction of modular plants which can be expanded as needed or kept small to minimize design-to-silicon times. The IC industry is increasingly being perceived as a service industry for customers rather than a producer of standardized product. This bodes well from the domestic industry if it adapts itself to the forms of decentralized decision-making which this orientation requires. The start-ups can do so, but can the larger merchants?

The bottom line is that the IC sector will probably survive as a source of both products and concepts. Ownership will be more diverse, and many companies with a wide range of products will be forced to retreat to specific niches. In addition, relationships between customer and buyer will be more integrated, although not to Japan's extent. Domestic firms will have a difficult time keeping market shares in commodity ICs. However, competition between East Asian producers is likely to make this a low-value-added and low-profit sector which will serve buyers better than sellers.

The IC Industry And National Defense

Were the U. S. IC industry to lose an increasing share of its home market to imports, the effect on the defense industry could not help but be negative. The key question is the significance of this impact. Will it relevant only to the industry's potential performance under mobilization or will it limit the defense industry's ability to access the leading-edge technology in peacetime as well?

There are three aspects to this question. The first is how and to what extent the declining status in the commercial market translates into a dependence on overseas sources for military chips. The second is how much difference it makes that systems houses have to go abroad for their chips. The third is whether losing the edge in the IC market portends losing the edge in downstream industries of relevance to national defense, such as supercomputers.

The commercial-military nexus: A smaller IC industry, by that fact, would be less capable of staying on the cutting edge of all technologies relevant to military systems. Trends in technological superiority are strongly influenced by trends in market share in several ways. An industry which is growing more slowly will have fewer resources to allocate to technology. With less opportunity to add capacity, its average plant and equipment will tend to be older and less state-of-the-art. Most ominously, if producers cannot make their otherwise successful R&D profitable on the manufacturing floor, they will do less research and development. This explains, for instance, why domestic firms are not busy doing R&D on consumer electronics. Although the domestic industry has not yet given up any major IC line, research on DRAMs here has dwindled as the number of potential US producers declines.

Thus arises the potential harm of overseas competition. On its own, the rise in Japanese manufacturing prowess is a plus for our national security. As allies, their ICs are more likely to find their way into our products than ours are. If their advances drive US firms forward, everyone is better off. It is only when Japanese competition drives Americans from researching, and thus making leading-edge devices, that the benefits of better devices from abroad have to be assessed against the costs of having worse devices from home.

Some argue that the military market for ICs is sufficiently specialized that the military segment could be a profitable niche for key producers to produce leading-edge designs within. The numbers are not there, though. Although certain aspects of military chip production are exclusively military, and certain chip types are favored in defense systems, military systems on the whole use all sorts of chip designs. A military-chip subsector would itself be incapable of being on the leading edge for more than a fraction of them. Roughly 80% of all military chips are essentially militarized versions of commercial chips and most believe (as expressed by a representative of Hughes Aircraft's IC operations) that the military demands too many different types of chips to be effectively handled by a military-specialized producer.

DoD, however, does buy a disproportionate percentage of its chips from firms whose military business is a large factor in their total workload. DoD uses 9% of the nation's IC production (4% by volume). However, 20% of its business went to firms which rely on DoD for over 45% of their sales (e.g. Harris Corporation whose bi-polar line supplies 1 of every 9 DoD chips). Another 20% went to firms whose military business is 30-45% of the total, and a third fifth to those 15-30% dependent. Only two-fifths went to firms which got 85% or more of their sales from commercial work.

Military chips do differ from commercial ones in many ways, most stemming from the basics of military procurement. One difference is that they have to withstand harsh environmental conditions such as wide temperature variations, vibration, high g forces and radiation. At present, a disproportionate share (perhaps well over 50%) of the value-added in military ICs comes from the testing (and associated documentation) needed to ensure high-reliability under such conditions.

(Most IC producers argue that the testing regime is based on antiquated views of the industry, is not cost-effective, and may even produce chips less reliable than commercial specifications. Many key IC houses now guarantee their chips to all customers as having less than 150 defects per million sold. Military tests are said to be incapable of detecting fewer than 1000 ppm defects.)

The importance of systems integration in military designs also tends to freeze hardware and software specifications early in the design process. It also prompts the use of standardized specifications (such as the 1750A 16-bit instruction set, or the ADA language) which are otherwise suboptimal for their time. Finally, the need to maintain fielded military systems creates a military demand for very old designs.

Table 30 shows the difference between military chips and commercial ones by chip category. Note that categories whose relative importance is declining show relatively high defense interest (compared to world commercial sales) and vice versa.

On average military chips are bought three to five years behind commercial chips. This fact correlates with the later timing of peak chip demand as well as a category-by-category comparison of current purchases. Just being introduced for military systems, for instance, are the first 32-bit chip (National's 32016) and the first 256K DRAM (Mostek).

The most telling example may be inferred from a review of DoD's own VHSIC program, established specifically to create chips for military use. As Electronics warned, "It remains to be seen whether military procurement policies can be updated as well to offer hope that VHSIC chips can be put to use before they become yesterday's technology."[23]

Table 30

Distribution Of Sales By IC-Type
(percentage)

	Military	World (1986)	World (1991)
Linear	26%	25%	21%
Bipolar	39%	21%	14%
MOS memory	11%	20%	29%
MOS logic	24%	33%	34%
Other	0%	1%	2%

SOURCE: ICE

However, within the military's demands is a small sector which is pushing the state-of-the-art regardless of cost. DoD often fosters very advanced ICs to meet the needs of its research & development projects, to prove out certain concepts, or to gain a technological advantage in its black (i.e. highly classified) programs. Such designs might include sophisticated radiation-hardened, advanced imaging circuits, specialized digital-signal processors, ultra high-speed designs and perhaps exotic materials. In these cases, price is generally no object. Companies competing in these technologies may be safe from foreign competition, since the Japanese are not interested in this market (with the possible exception of space-hardened ICs).

This latter business (the perhaps 20% that is on the cutting edge) is probably the largest niche that could conceivably be supported based on its technological edge (the entire military sector could be supported with buy-American restrictions but that would not necessarily yield a state-of-the-art sector). Losing contact with the commercial side of the business places the industry at risk of catching all the bad habits resulting from a dependence on military procurement, rather than just some of them. Such a small sector ($300 million?) may not be supportable without having to access generic IC technology available elsewhere. If this elsewhere is overseas then the same problem reemerges in another form.

Direct Impacts of Dependency: To what extent would being forced to go abroad compromise the US access to the leading-edge technology?

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23. Electronics, 16 April 1987, p. 84.

If domestic IC producers were forced off the cutting edge, defense systems houses would be hurt in three basic ways. Working relationships with IC vendors would be more difficult, access to existing IC devices would be delayed, and security risks would arise from sharing designs overseas.

Greater difficulties arising because IC producers are overseas would show up in many ways. Overseas producers, unless strongly tied to the US defense market, would be less likely to look for military applications of their products, and more likely to be governed by alternative commercial concerns. Bubble memories, an environmentally hard offline storage device may serve as an example. Intel, a domestic firm, had bent its research towards increasing the yield of devices which can operate at temperatures demanded by military applications. Japanese firms, meanwhile, were more interested in commercial applications such as higher data-transfer rates. Were US start-ups unable to pick up where Intel left off in bubble memories, the technology would be apt to be developed in paths away from military applicability. Japanese producers of gallium arsenide chips (useful for high-speed image processing), as another example, have been reported to be reluctant to do SDI work for fear that U. S. firms will learn their technology. A third example may be adduced from a chip recently developed by Texas Instruments (with Defense Advanced Research Projects Agency money) to run LISP (an artificial intelligence language). The Japanese, having chosen Prolog, a vastly different language, as the medium for their fifth-generation computer project, would, one might expect, have been reluctant to undertake such work (except that NT&T is now claiming to have developed the world's fastest LISP processor).

Many Japanese IC houses are also reluctant to work directly with US military designers unless they could claim that such chips had dual-use characteristics. Such reluctance stems from their interpretations of Japanese government policy. It remains to be seen whether the current defense technology transfer negotiations between the US and Japan will alter this attitude.

Geography itself tends to inhibit a close working relationship between overseas sources and our defense houses in designing leading-edge devices into military applications. Even in this day of easy communication, industries continue to clump together in certain regions, such as Silicon Valley or Massachusetts's Route 128 for electronics, or the Los Angeles basin for aerospace. Proximity allows people to exchange ideas (and jobs) easily. Day-to-day interactions between customer and producer are more frequent, with shorter turn-arounds. Much of this interaction would be lost if IC development went overseas.

Language is another barrier. A Texas company, Convex, is currently developing a super-mini-computer based on a new Fujitsu

20,000 gate logic array. Fujitsu got the business because they helped support the previous generation with an 8,000 gate logic array when few others would work with a start-up. But none of this would have happened had Convex personnel not taken the initiative to learn Kanji, the Japanese alphabet, specifically to access the technology.

Delays in getting leading-edge from overseas would arise from many causes. Some Japanese IC producers may be reluctant to release chips to market if their corporate parents, who are generally large computer/electronics firms, sought more gain in using such chips to gain a competitive edge in downstream products. Our defense producers may get access to these chips only as the technology is maturing. In addition, defense producers, who might beta-test new domestic designs prior to release, would be less likely to be introduced to new designs from overseas companies.

The length and nature of this lag is subject to dispute. Many experts hold that integrated Japanese firms fill in-house needs first before selling ICs outside (but US firms do the same). It would be more salient if Japanese companies supplied each other first before they offered their best ICs to foreigners, but there is less evidence that they do so. As to the length of the lag, a Cray computer executive estimated it at six months, but others suspect that it could be as much as a year or two.

Japanese firms are also beyond the reach of the Defense Production Act which allows the US Government to compel on-time deliveries of military ICs and other items even if lead times for commercial customers are growing. If supplies get tight lead-times for chips would expand greatly and US customers are likely to feel it worst. (This also works both ways. Japanese customers had difficulties in getting US microprocessors in 1983-84.)

Security risks are another problem in accessing Japanese IC capabilities. Defense houses may have to work closely with Japanese producers in developing designs. There are many systems for which DoD would be (properly) reluctant to see developed offshore. Among them are black programs (whose entire existence is supposed to be secret) and any project which develops new technologies which might be copied in the process of being worked on.

Foreign policy may present other risks. Although Japan is among our staunchest allies, political forces in the future may create inhibitions to their supplying certain defense needs. Past examples include Sony's withhold of a TV camera for missile-mounting during the Vietnam War or the recent debate in the Japanese Diet on whether to forbid Kyocera from supplying ceramic packages for cruise missile ICs. There may also be cases where Japan may want to keep certain militarily-useful technologies to themselves, or to use the threat to gain access to technologies which we have and are reluctant to release to our allies.

Many are also concerned that overseas producers may be less willing or able to keep classified IC designs from falling into Soviet hands. Although Japan, the most likely overseas producer, is a member of COCOM with a good record of guarding military technology, private Japanese firms (e.g. Toshiba Machine) may be less conscientious about preventing dual-use technology from falling into the wrong hands. Nevertheless, nothing done to bolster the US IC industry is likely to affect the transfer of technology from Japan to the Soviets.

Several factors could change this assessment of the problems of accessing Japanese ICs. The Japanese Government may began to favor a Japanese export role in military equipment. This would make it easier for US defense firms to work with Japanese IC firms. But it would also give Japanese firms greater reason to withhold military ICs in order to give their electronics shops competitive advantages in the world arms trade. The growing links between Japanese IC houses and those of other countries, on the other hand, would enhance the proliferation of technologies across national boundaries. Another large change would be the emergence of South Korea, together with Japan, as representing the leading-edge technology. Geography has forced South Korea to be more defense-minded (and conscious of its US ties) than Japan and much more likely to work with US defense firms.

<u>Would IC Dependence Create Subsystem Dependence</u>? There are several militarily interesting sectors--supercomputers, avionics, telecommunications, solid-state radars, etc.--where IC technology could be leveraged by the Japanese to increase market share. Currently, supercomputers are the most salient example because of their criticality to electronics intelligence and the importance that both DARPA and Japan's fifth-generation project assign to them. As it happens, American supercomputers are dependent on Japanese memory chips without which they would not function.

Currently, the US firms (Cray and ETA) account for 286 installations (early 1986) versus 41 for all Japanese firms. Within recent years, Japanese producers have claimed higher processing speeds, and have been accused of using import restraints to preserve the home market for their own companies. With the development of a Japanese supercomputer in mind, potential Japanese customers, particularly those associated with the Japanese Government, were inhibited from buying supercomputers until Japanese models were available.

Observers have suspected that Japanese firms are withholding their best ICs from the market where they have a chance to leverage their technology into market share for supercomputers. One case in point is the rumor that the Japanese have developed a DRAM with a very fast access time (55 nanoseconds) which they are saving for their own supercomputers but not selling outside (it is not clear whether individual Japanese firms are selling this chip to among themselves). It has also been suggested that such behavior is being repeated in the supply of GaAs circuits. As Electronics notes:

> Although Japanese semiconductors are not as innovative as Cray's GaAs chips and ETA's cryogenic CMOS chips the Government's high-speed computer project will most likely build a supercomputer with high-electron mobility transistors (HEMT) improving the price-performance ratio of their machines.[24]

As the director of Fujitsu's Atsugi lab explained, although he would be more than willing to help US companies use Fujitsu's GaAs chips in their computers, the second-generation devices built with HEMT technology are being reserved for in-house use. They regard the latter as having significantly superior price-performance characteristics.

The key question, that only time will answer, is the degree to which the synergy between ICs and their using industries are so great that withhold strategies of Japanese IC producers are sufficient to give them a large edge in this market. For the time being, the US lead in supercomputers is solid. US producers are taking alternative approaches to supercomputing. IBM, for instance, recently introduced vector processing to their 9300 series mainframes, giving them supercomputer capabilities. Other US companies are taking world leadership in minisupercomputers (which, roughly speaking, offer one-third the performance for one-tenth the price), parallel processing machines and neural-net computer research. The Japanese appear to be ahead only in logical-inference hardware.

Conclusions: There are subtle but significant relationships between America's leading edge in ICs and its ability to keep a leading edge in defense production. If US IC producers cannot stay on the leading edge then users of military ICs will be hindered in getting access to leading edge technologies. In some cases DoD would be reluctant to send designs overseas for development: in other cases, Japanese companies would be reluctant to work for defense houses. Technologies with general application to military requirements would be less likely to be developed in countries with a small defense sector; similarly the day-to-day contact between chip-makers and their customers, which characterizes the US market, would be harder (but not necessarily

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24. Electronics, 7 April 1986, p. 42.

impossible) to duplicate across the ocean. Other fall-outs include a palpable loss in competitive edge to key dual-use electronics industries which are heavy IC-users.

Ways can be found, at some cost, to live with these problems--having US defense houses locate more purchasing agents or design groups in Japan, putting a patina of dual-use on technologies they get, and perhaps yielding greater leverage to Japanese partners in subcontracting defense work (either theirs or ours). It is instructive to note that the major systems houses, according to one study, are relatively insensitive to the potential demise of the IC industry in the belief that their in-house facilities are equally capable of keeping them on the cutting edge of that technology.

But any loss in access is bound to hurt, and many of the adjustments that defense houses could make would only put US IC producers in a poorer position relative to their overseas competition. The same may be said about linkages between ICs and downstream industries. Firms may be expected to leverage advances in one to help their position in the other; only the degree of leverage between the two is unknown.

Policy Options For The IC Industry

The argument that links the health of the IC industry to the national security via its impact on weapons systems production is not robust. It requires one to believe that:

- the merchant IC industry may be unable (and the captives unwilling) to support DoD's needs, and
- the technology lags from going overseas are large, and
- helping the entire industry is a cost-effective way to maintain the pace of IC technology insertion into military systems.

None of these propositions is obvious and all must be true for the argument to work. If Government action is to be justified, a broader argument may need to be made based on the links between the IC industry's performance and those of supporting industries in the world market. These supporting industries would have to be a necessary portion of the defense industrial base writ large (to include research facilities etc.) particularly that sector that hones its talents in commercial competition.

The status of the industrial base as a whole would be strongly related to America's status as a technological culture, not just as a consumer but as a producer of relevant goods and services. If America's economy cannot keep up in manufacturing, the basis of our foreign trade may deteriorate to the export of commodities, niche products and services. While economically viable (assuming we make efforts to retain them), it sets the defense industries asunder from the commercial considerations of cost, quality and producibility resulting from world competition. In time, this could not help but limit America's ability to produce high-tech weaponry.

As such the linkages between the performance of the IC industry and national security as a whole would be real. They draw their strength not only from the use of ICs in military products per se, but from the contribution that each constituent industry contributes to a strong manufacturing sector, and from there to our technological culture in general.

The IC industry can be aided by generic industrial policies and/or specific industrial strategies. Generic industrial policies would cover education, taxation, antitrust, trade etc., driven by overall indicators of the nation's productivity, trade, economic performance and not the health of specific sectors per se. Although industrial strategies are not yet within the accepted purview of the federal government, there are industrial policies of various sorts, which do set the rules in which industry works. How they are administered constitutes, in effect, Government's industrial strategy. Indeed, Government-sponsored research and development or military purchases in general cannot help but be technology-specific. It is a small step from that point to being industry-specific. What turns these policies into specific industrial strategies is the conscious recognition that they affect industry performance, in the large, in distinct ways. Specific industrial strategies, in turn, must perforce be guided by some consideration of what the affected industry is to look like.

The primary output of a good IC industry is precisely the capabilities, quality, variety and price of its products. That is how it best serves defense as well. One would also want such an industry to be viable over the long term. Government support will surely inhibit its commercial competitiveness.

Over the last few years, another goal has arisen. A healthy domestic IC industry should be able to trade technology information at a reasonable rate with its potential competitors. It should not be forced to yield its knowledge base to other countries' firms (because of their superior financial or technological muscle) without getting back anything in return. For that to be the case, it has to remain leading-edge in enough areas to be able to trade technology as equals. If it cannot develop first-rate technology it will not have the power to acquire it in any other way.

Understanding the proper place of the industry's Japanese competitors is essential to proper consideration of an industrial strategy. It matters which conflict is important: if the economic one is paramount then the Japanese are opponents. However, from the national security point of view, the Soviets are the ones which threaten our well-being. In contrast, competition from Japan gives military users greater choices than before. As long as US industry is not left in a demonstrably inferior position vis-a-vis the Japanese, national security can only be helped. From this perspective, the goal is an industrial strategy, designed not to wage economic warfare, but to maximize the terms of trade between the US and Japan, so as to derive the maximum advantage from these opportunities. The strategy then involves determining what kind of US industry we need in order to take best advantage of these opportunities.

Strengthen Cooperation? The primary consideration is whether to go with the flow of technological expertise to Japan and work to enhance access there, or instead work to strengthen the ability of the domestic industry to compete against it.

These goals have contradictory. DoD's acquisition policies could have a significant effect on the desire of overseas IC producers to work on military applications. If DoD signals a strong bias towards domestic producers (e.g. R&D funding, participation in key programs) and a strong bias against overseas producers (e.g. discouraging the use of foreign ICs, or where used, designing around or second-sourcing them) then overseas producers will be less interested in seeking military applications of their technology. The alternative is to open defense procurement more widely to overseas sources (and encourage the Japanese Government to consent to such dealings). Doing this, though, would remove the advantages enjoyed by domestic suppliers in competing for defense work, increase the work going overseas, and so exacerbate, first market position and then technology trends. Ultimately, the access of military systems producers, though helped directly, could be hurt indirectly.

A strategy to assure access to leading edge technology through structuring cooperation with Japanese companies may have other aspects. One would use trade negotiations as a lever, not to regulate Japanese imports but to encourage the greater dissemination of information from Japanese research to American aspect production. At present, there is considerable asymmetry between the US and Japan as regards information flow. Much of ours takes place in universities where information dissemination is second nature: in Japan, the research that is done in government-industry consortia generates information that is limited to its participants. If such consortia included, among others, IBM Japan or Texas Instruments, Japan, their information would disseminate here faster (and, not incidentally, encourage more US companies to set up there). It also matters whether US subsidiaries of Japanese companies have full access to Japan's technology or are treated as poor relations. Had Fujitsu been allowed to buy Fairchild would the former have lent its HEMT to the latter? Should such access have been a precondition of Government approval for that purchase?

Whether we think a "join-them" policy is better than a "beat-them" policy for ensuring access to leading-edge technology is strongly influenced by our perceptions of their strategy and their perceptions of our markets.

This reintroduces the Japanese challenge to the domestic IC industry. Japan is often perceived to be a monolithic commercial culture, intent on dominating the information industries of the twenty-first century, and not satisfied with anything less than 100% of the key markets on the way to this goal. This perception colored Government's attitude of the potential purchase by Fujitsu of Fairchild. Fear existed that the Japanese firm would drain Fairchild of its unique technology and leave a carcass behind.

In reality, the major Japanese companies are independent corporations, and they are incapable of exercising much collective power without the active participation of the Government. The Government's role, in turn, is limited to certain areas such as fostering basic R&D, regulating the domestic market (particularly for imports), encouraging corporate link-ups (e.g. the creation of Nippon Steel) and putting subtle pressure on banking in favor of corporate finance. Over the last ten years, however, the Japanese Government has, if anything, been less capable of exercising power. As Japan has less need of technological imports, for instance, MITI's authority over import controls grows less meaningful. As the major electronics firms have grown larger and affluent, MITI's leverage over their potential combinations and finances has been harder to engineer. While MITI continues to work Japan's technology strategy, it is largely telling industries to grow in directions to which they were inclined in the first place.

The enormous decline in DRAM prices in 1985-86, as an example, is very difficult to ascribe to any Japan Inc. strategy. MITI's view is quite opposite: that, in fact, the urge of various Japanese companies to make DRAMs was counterproductive, leading to excess capacity, and destructive of any profit potential. Now that DRAMs are a money-losing business, MITI has pressured the industry to reduce capacity; but this runs counter to what Japan Inc. was supposed to have done to drive US producers from the market. In any case, any long-term gain to be had from driving American firms from the market was bound to be dissipated by the entrance of Koreans and perhaps other Asians into the market.

For their part, if Japanese IC firms perceive themselves as subsidiaries of Japan Inc., then encouraging them in the defense market will create more vulnerability to outside influences than if they perceive themselves as true multinationals. As the latter they would naturally optimize decisions on a worldwide basis rather than what would be best for Japan. Ultimately, for instance, NEC's US manufacturing and research facilities would be no less American than those of Motorola, and they would care little whether their profits were taken in California or Japan.

In general, the links between Japan and its corporations are explicit (via NT&T's research facilities or the Government-industry joint projects), implicit (links between the Government, the banking system, and heavily debt-laden firms) and cultural (the oft-observed group orientation which characterizes Japan). In comparison, American multinationals and, especially, European multinationals are more truly international concerns. No one expects Signetics to be operated in the commercial interest of the Netherlands (which houses its corporate owner) or Mostek in that of France.

Some evidence--e.g. greater overseas investments and US production facilities--suggests that Japanese corporations are moving in that direction. But by most standards, Japanese firms have a long way to go before they match the multinationalization of American or European firms. The Japanese External Trade Relations Organization (JETRO) estimates, for instance, that Japanese firms do only 4% of their production abroad, versus 17% for US firms and 20% for German ones. A study last year by Professor Noritake Kohbayashi indicated that, on a scale of five (representing the most multinationalization), Japanese multinationals measured at 2.75 in 1978, and 2.85 in 1985 on the way to a 3.3 rating sometime in the future.[25] By comparison, multinationals in U. S. and Europe rated 4.1. Some Japanese firms (Sony, Honda, Matsushita) are more willing than others to go their own way regardless of the influence of MITI or supporting financial institutions; but they are exceptions, not the rule. A policy which plays to the odds that Japanese corporations will multinationalize sometime in the distant future may have to be considered betting on the come.

<u>Strengthen the Domestic Industry</u>? The other approach, strengthening the domestic industry to take on the Japanese, begs the question of how this is to be done, and alternatively, what is to be fixed (and why market does not do this automatically).

One has two approaches. The first, which denies industrial strategy, is to look for ways to alter industrial policies to ensure that the integrated circuit industry is not unduly

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25. <u>Economist</u>, 7 December 1985, p. 30.

hampered from market-oriented actions. The second is to embrace industrial strategy and deliberately consider policy alternatives in terms of how they affect an industry's development.

The three generic policies which most saliently affect the IC industry are trade, antitrust, and export controls.

It is becoming clear that helping the industry through trade negotiations alone has failed. In mid-1986 the US government negotiated an agreement with the Japanese government that would:

a. set minimum cost-based prices for certain memory chips
b. maintain this price in third-country markets, and
c. double US exports to Japan.

At the time of the agreement, most observers were skeptical that the latter two were enforceable. Time showed that they were not, even though recent trade restrictions against selected Japanese imports are a systematic attempt to deny the obvious. Within the American market itself, this agreement has had three effects; two bad, one probably good. The first is that many electronics firms started buying chips in third-country markets and installing them onto circuit-boards for re-import to the US, thus sending more value-added abroad. The second is that, insofar as prices held, most of the added revenue from this agreement accrued to Japanese firms, who could then recycle this money into R&D and hence new and better products competing against those of US firms. The third is that some Japanese firms have expanded their memory production in the United States. By now, the agreement has virtually collapsed as a viable approach to economic assistance although the political ramifications continue to echo.

A similar approach is to strengthen the market by removing certain antitrust and export-control barriers to competitiveness. At present, export controls, especially to allies, are being reviewed to make their application less onerous to high-tech firms. Other suggestions include relaxing the application of antitrust laws in industries where foreign competition is sufficient to keep US producers on their toes. Both would help the industry, but neither addresses its basic problems.

This leaves industrial strategy. Consensus holds the domestic industry suffers from two basic problems. One is that it can design chips well in advance of its ability to produce them in volume (economically). This fact is becoming evident as a problem in the VHSIC program. Admiral Inman, the first head of MCC, the industry-wide R&D consortium, cited the lack of an adequate receptor capability to quickly convert new technology for advanced designs and technology as the industry's largest problem. He added that the gap between available technology and the technology in day-to-day use continues to widen. The other, perhaps more ominous, is that it is underinvesting in its long-term technological strategy in favor of research on chips due soon to market.

Most of the debate on helping the IC industry has centered on Sematech, a proposal developed by the Semiconductor Industry Association for a giant manufacturing research facility.

As originally proposed, and as endorsed by the Defense Science Board, Sematech was to have been a joint industry-Government consortium whose purpose was to build and run a leading-edge world-scale facility to produce DRAMs. This facility would have attempted to recapture the US position in the DRAM market at the 4 megabit level. By so doing it would also serve as a test-bed for new semiconductor equipment designs and electronic materials. The total envisioned investment was $250 million/year for five years. DoD would supply 50% of the funding, most plausibly in the form of targeted research contracts.

Within the first six months of 1987, the focus of Sematech shifted in subtle yet significant ways; in so doing, it has been transformed from a dubious proposition to one meriting consideration. The shifts were twofold. First, Sematech would be oriented towards research and development in manufacturing, not in creating a production facility. Process, not product, would be its focus. As a manufacturing facility, the need to justify itself through its attempts at profit-making would have created an indefinite lifespan and, perhaps, an equally long Governmental commitment. As a research facility with a distinct goal, it is much less open ended.

The second shift was away from DRAMs as such and towards SRAMs (static random access memory). US producers still have a viable market position in the latter and could transfer the production knowledge gained towards maintaining their market. In DRAMs, the challenge would have been more quixotic and less tenable. At first glance, DRAMs looked like a logical candidate. The volumes are high, US competition may otherwise be absent, and DRAM production techniques are said to drive all IC production technologies. This is largely because DRAM production tends to lead other chips towards ever-finer geometries. Since they are easy to design, the entire challenge is in placing them on a sufficiently small piece of error-free silicon. But while DRAMs are the best technology drivers (and are used as such by IBM, AT&T, and TI), others make do elsewhere. Intel, for instance, uses erasable programmable read-only memory (EPROMs); National and Signetics use logic devices; Motorola, Fairchild, Performance and others use static memories (SRAMs). Indeed, SRAM, where the US merchants still compete, is increasingly touted as the better tech driver. To quote <u>Electronics</u>, ". . . as some proponents contend, DRAMs appear headed outside the technology mainstream since they need special structures--such as trenched storage capacitors--to reach beyond megabit chip densities."[26]

The best reason for staying away from making DRAMs is precisely because other countries--Japan as well as South Korea but also a German-Dutch consortia, and even East Germany--are trying to get in the game. This is a sure sign that everyone is going to lose money at it. As a Andrew Prophet of Dataquest noted, "If you thought the price attrition in 64K and 256K [DRAMs] was bloody, wait until you see what happens in 1M DRAMs . . . fortunately, most of the competition will be between Japanese and Korean companies."[27]

The added focus on semiconductor equipment comes because both industries believe their health to be intimately linked. At present, however, no one IC firm can influence the development of equipment or the status of its suppliers. It is the market which has to be wide enough to justify the large expenses associated with product development. Yet, if the domestic industry weakens, its demand for new machinery will lag; Japan will become the locus of new innovation, and eventually its semiconductor equipment industry will relegate the American one to a niche status or worse. It is believed that US producers will not be sold Japan's best technology; this competitive disadvantage will make the industry as a whole weaker and continue the downward spiral. Contrariwise, the Japanese industry was able to grow on the basis of US-made equipment and their research consortia are still built around US-made equipment.

Would Government support be a good idea? Some argue that modest Government help would be warranted as a reward for the industry's collective initiative and willingness to try new ideas. True, a $625 million contribution from DoD hardly qualifies as modest. However, the industry makes a credible case that significant cuts from that level would make it difficult to do the collective research necessary to get geometries down to the goal of a third of a micron. Sematech's organizers have carefully laid out a series of intermediate research goals required to meet targets within five to six years: these research goals in turn have generated 28 separate research tasks, each with its own resource requirements. It is not clear that the US industry can stay competitive in process technology per se if it takes more than five years to get to the goal: Japanese efforts are continuing in that direction unabated. Thus, while such a large contribution requires a leap of faith, there may be no other way to bridge the gap.

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26. Electronics, 7 August 1986, p. 121.

27. Electronics, 16 October 1986, p. 80.

If a manufacturing consortium is necessary, an alternative but smaller facility might be a state-of-the-art silicon foundry to make ASICs. ASICs have several advantages over memory chips. The overall market is growing, and represents a playing field where US producers are likely to survive (the DRAM game, according to most, is over). Another is that the closer interactions between buyer and seller in making ASICs portend a significant loss of access by military houses if US firms are driven from the market. Finally, military demand for ASICs is sufficiently high that Government demand alone could keep the facility occupied; the same cannot be said for memory chips which are not found in military systems in sufficient numbers.

Another use of Government resources is to create opportunities. Historically, DoD has best motivated industrial progress by purchasing items for military use ahead of the point at which economics would motivate a large commercial market. The semiconductor industry itself was so started; but other industries such as aerospace or computers were substantially aided thereby. With some imagination, there are many IC or IC-using products which could benefit from this approach. Gallium arsenide ICs may be entering this phase now. Other candidates include high-speed SRAMs for smart cards (at present the only Government market is being made by the Department of Agriculture). Another possible approach is to, replace en masse, all the hybrid linear integrated circuits in PGMs and other electronics, with ASIC devices from US vendors. Such conversions would create a critical production mass in the industry, lower weapons costs over the long run, and make surging weapons production easier all at once. Government as a buyer creates industrial strategy which conforms to, rather than leans against, the market. DoD's unique technological expertise allows it to be as good one as well.

One step that the Defense Department could take on the industry's behalf would save DoD money as well. This would be to make consolidated advance purchases of those ICs which are already designed into its current weapons systems. This would stimulate industry when commercial orders lag. But it should also reduce the overall costs of buying chips and enable DOD to better accelerate production of critical weapons systems in emergencies.

To the extent that industry may be underinvesting in long-term technologies, Government may also play a useful role in supplementing its R&D. To a large extent, the Department of Defense is doing just that with projects ranging from the established VHSIC program and the emerging MMIC (millimeter microwave integrated circuits) program to the specialized devices being developed for SDI and DARPA's strategic computing project.

Although more resources would not hurt, a stronger case can be made for integrating the disparate research grants into a coherent industrial strategy. If international competitiveness is to be promoted, then the chips should be produced so as to be commercialized as quickly as possible. This affects both the choice of technologies to pursue and the selection of contractors to pursue them. At present some DoD programs do this although the weapons-specific nature of the funded research means that commercialization is pursued not for competitiveness reasons but to speed insertion of technology into military-relevant systems.

One such program is DoD's near-billion dollar effort to develop very high-speed ICs (VHSIC). Reviews to date are mixed on its applicability to commercial work. Electronics had reported that "many [IC firms] also worry that it [VHSIC] may be too narrowly focused for its technology to make its market in commercial products".[28] However a later article gave the program high marks reporting that many producers are now trying to get their facilities qualified to VHSIC's Phase I standards. Also, the chips originally produced for the program are finding their way into commercial markets.

It may very well be that commercialization was never the intent of programs, such as VHSIC. Larry Sumney, who created the program, recently noted:

> The idea [for VHSIC] at the time was that our commercial industry was far and away in the lead position in the world and in the US We saw all this capability in the commercial sector. We did not see corresponding capability in the aerospace houses. What we wanted to do at that time was to form mergers, or alliances, or partnerships that will allow the infusion of technology from the commercial houses in[to] the aerospace houses.[29]

More clues can be gained by looking at the program participants. VHSIC contractors, GaAs contractors and MMIC bidders include such firms as Hughes Aircraft, GE, TI-Raytheon, Westinghouse, Rockwell and TRW. These are not IC producers as such but defense contractors who happen to have a IC facility. Unless it continues to be DoD's intent to solve its own IC technology problems by building up a core group that is responsive to and beholden to military procurement (a DoD "hothouse" to quote Prof. Ed Feighenbaum), it is not dealing with enough of the right companies.

There are other options for boosting long-term R&D funding. One is to copy the Japanese and promote (and perhaps fund)

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28. Electronics, 18 December 1986, p. 92.

29. Defense News, 1 December 1986, p. 30.

industry (Government, university?) product-oriented research consortia. Another is to reorient the national laboratories in the direction of more ultimately commercializeable research--perhaps strategic partnerships with industry to support jointly funded (and managed) projects. A third is to revisit the AT&T divesture decision with the aim of making Bell Labs the technology promoter that Japan's NT&T is.

It should not need saying that the Government cannot make up for every ill in the industry. In manufacturing, the IC industry is aware of its relative inefficiency vis-a-vis the Japanese and has a very direct bottom-line interest in fixing it. Consider, too, the progress the industry has made against the perception of deficient quality control which was widely reported as an industry problem in 1980.

One of the oft-cited problems in this sector (as in many others) is the lack of a long-term strategic vision among senior management. To the extent this is so, more money in R&D will not, itself, do much good if the advances developed in a Government-supported laboratory are not carried through to fruition on the production end. Some of the lack of long-term vision arises from the day-to-day uncertainties imposed by the industry's financial structure and exacerbated by the recent losses that may prevent many companies from having a long-term future at all.

One solution (qua Charles Furgeson) would have Government promote the merger of IC producers and their customers. This would lend affected sectors some stability and better market information. However, if the suppliers themselves are similarly short-term oriented and/or expect their IC operations to be short-term profit centers, it is difficult to see what good this will do.

Another possibility is for (quasi-) Government extended low-interest loans against identified long-term investments, which could be converted into equity and resold to the open market. There should also be other avenues for financial restructuring which would both finance the industry and leave its technology on the cutting edge.

Conclusions

The problems of the IC industry are fundamental to this country's ability to maintain its position as a high-technology producer. At present the industry seems to be falling behind the Japanese in the development of many key production technologies: this may or may not presage a time when defense producers will be more dependent on overseas sources for their ICs.

Should that happen, some difficult choices will have to be made to maintain access to the leading edge technology in this area. One choice is to draw the Japanese firms into the military procurement orbit and use whatever leverage the United States has to allow domestic sources more access to Japanese technology. The other is to strengthen the competitive position of the domestic IC firms, a process best accomplished by increasing R&D in one form or another.

A mix, strengthening cooperation or strengthening the industry, is possible, although the contradictory elements should be explicitly recognized. In either case, whatever path is chosen should be considered in the context of some coherent strategy for the industry. Such strategy should clearly identify the relationship between the industry's health and national security, the desired form of this industry, and the path from here to there.

SECTION SIX

Policy Options, Summary And Conclusions

As the discussions of the previous sections have shown, the range of policy options available to address the issue of foreign source dependence and vulnerability is broad. But the preceding discussions have yielded insights to help narrow the focus of the policy decisions.

First, tools are available to enable policy makers to set priorities for analysis as well as for action. Policy makers cannot take action on every incidence of a purchase of materiel from foreign sources; they cannot even ask for a detailed foreign source analysis of every DoD program. The level of analysis that went into the discussion of PGMs in Section Three, materials in Section Four or ICs in Section Five cannot be performed for every DoD purchase. This sort of analysis is not free. The discussion in Section Two helped set priorities by establishing criteria for the selection of the most critical weapons systems and technologies. The framework presented there is one of many that could be constructed. Its value is in its comprehensiveness. Rather than randomly choosing weapons systems to examine, this framework--or one like it--allows the policy maker to allocate the limited resources--programmatic as well as analytic--to the most important systems and industries.

Second, if policy makers cannot be concerned about every incidence of purchase from abroad, happily they need not. The discussion in Section One demonstrated that vulnerabilities--those foreign sources for which policy action is required--are a subset of foreign dependencies, themselves a subset of all foreign sources. For PGMs, roughly 98 percent of the value is added in the United States or Canada. Of the two percent originating abroad, many of the sourcing decisions were driven by cost and quality considerations, not domestic availability--that is, in a crisis, these parts could be provided by domestic firms. Of all the parts that go into PGMs, only 22 are true dependencies, by our definition. Of these 22, eight come from the United Kingdom or Mexico, presumably secure sources in nearly all conflict scenarios. We are left with only 14 vulnerabilities in the PGM class of weapons.

How does the policy maker address these vulnerabilities? Alternatives can be grouped into three generic strategies which we have called: Status Quo, Buy American and Buy World.

Status Quo

The Status Quo strategy is a mixture of policy directives and guidance that emphasizes at once preservation of the defense industrial base, arms cooperation with Allies and competition. Told to preserve the domestic industrial base, a program manager would try to buy from domestic sources. Told to maximize arms cooperation with Allies, a program manager would explore cooperative development and production arrangements with NATO Allies. Told to emphasize competition, a program manager would seek the widest range of prospective bidders on his program--including Japanese, Israeli, Korean, Brazilian, et cetera. The program manager clearly cannot meet all three objectives at once.

Buy American

A requirement to purchase all items of defense materiel from US sources would reduce the chances of disruption during a crisis. It would remove the threat of foreign competition from domestic suppliers of services and equipment and increase the demand for their products. Domestic suppliers could increase both their DoD market share and their price to the Government. The resulting increase in the costs of defense materiel would represent the price of the insurance premium necessary to avoid disruptions in production during crisis. The technology available under a Buy American strategy would be the best domestic technology--which, in some cases, will not be the best in the world. Cooperation among US and Allied industrial bases would be essentially precluded and weapons standardization would be difficult. Allies and other nations would feel pressured to adopt similar, restrictive measures, thereby reducing the market for US products.

Buy World

Alternatively, a requirement to set quality standards and then purchase DoD materiel from the lowest-price source in the world that meets those standards would ensure DoD obtained its requirements at lowest cost. The technology available under such a Buy World strategy would be the best in the world. Joint ventures among US and foreign firms would be possible. To the extent that purchases under this policy were from insecure or potentially inaccessible sources, the chances of disruption during a crisis would be greatest. Less competitive domestic firms would lose sales and, unless they became more competitive, could go out of business.

The trade-offs between access to the most efficient producers, cost considerations in periods of constrained budgets, international political advantages of armaments cooperation, health of the domestic industry, and security of supply are obvious and yet difficult. Clearly there are choices more interesting than the pure strategies of Buy American and Buy World, and more effective than the current Status Quo. A strategy designed to take advantage of all free-world resources while managing risks entailed in foreign purchases is clearly called for and will be described below. However, before considering that strategy, consider another, less-discussed factor: the future structure of the world arms and world technology markets.

Future Market Structures

Consider two polar alternative structures of the world technology market. Call the first "Nation Inc." Technology firms tend to shun ventures with foreign firms, and governments provide significant funding to, and control over, their domestic technology firms. DoD acts like a stockholder in US technology firms. USA Inc. competes with Japan Inc., West Germany Inc., Israel Inc. et cetera.

Call the second "Multinational Inc." Technology firms become increasingly entwined across national boundaries. Governments exert little control over the flow of technology. DoD acts like a consumer in the international advanced technology market. International technology firms compete with other international technology firms, irrespective of the locations of corporate headquarters.

From the stand point of DoD access to state-of-the-art technology, which market structure is preferable? The advantage of Multinational Inc. is that the level of technological sophistication available to one country is likely to be very close to that available to another. That is, DoD is more likely to have access to the full range of state-of-the-art technology, including that from overseas. The disadvantage is that the US Government would have less control over the technology.

The advantage of Nation Inc. is that the US has access to, and control over, leading edge technologies in the possession of US owned firms. The disadvantage is that it jeopardizes DoD access to other leading edge technologies.

Soviet access to state-of-the-art technology under Multinational Inc. as compared to Nation Inc. is not clear: some argue that the Soviet ability to steal technology makes export control attempts futile. The persistence of the US lead over the Soviet Union in technological capabilities may be evidence that the current controls are having some effect--or it may be evidence that technological diffusion is a complex, difficult and time consuming process. That the technical sophistication of systems now fielded by the Soviets is comparable to that of the US is evidence that the time between conception and operation is excessive in the United States.

If, on the one hand, the leading technology in a field is in Japan, it is Japanese security that the Soviets must foil, no matter which market structure prevails. In the Nation Inc. world, the US may not have access to it, while the Soviets steal it. If, on the other hand, the leading edge technology in a field is in the US, and if Japanese security--or the security of any country with access to the technology--is inferior to ours, then Soviet access to the technology is marginally enhanced.

From an even broader perspective of national security, which market structure is preferable? To the extent that the Soviets are deterred from initiating conflict with the US due to the economic prowess of the US economy and mobilization potential, deterrence is enhanced if US economic power is augmented by that of Japan and Western Europe. That is, from the Soviet perspective, if the United States operates within, and its firms are intimately tied to, an economic network that includes the democratic and capitalist countries of East Asia and Western Europe while the Soviet Union operates principally within an economic network that includes its allies, Western strength is clearly superior to Soviet strength and deterrence is enhanced. To the extent that the Western economic network is fragmented into various Nation Incs., the strength of that network is reduced.

From the Soviet perspective, access to the technology is not the issue; with time and at some cost, it can be stolen. The issue is understanding and applying the technology. If the technology can be obtained only by theft, its application of the technology will be retarded. If the Multinational market structure prevails, the USSR must confront the combined economic and technological capabilities of the US, Japan and Western Europe.

In this regard the Defense Science Board (Malcolm Currie's DSB task force of June 1984) found that the strategic value of closer technological cooperation with Japan outweighs US industries' fears of Japanese competition in high-tech fields.[30] The DSB report also recommended a reaffirmation of US technological leadership as a firm national goal, supported by research and development funding. They too saw a strong US technological base as enabling the recommended cooperation and competition with Japan.

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30. Office of the Under Secretary of Defense for Research and Engineering, Report of Defense Science Board Task Force on Industry-to-Industry International Armaments Cooperation--Phase II--Japan, (Washington DC: USGPO, June 1984).

Maximize Opportunity, Manage Risks

A strategy that would take advantage of the technical and production facilities of the Western economic network, even as we reduce the major risks inherent in purchasing materiel from sources outside the United States and Canada, would appear to be best for the United States and its Allies. Elements of such a policy are these:

- o Set quality standards
- o Accept bids from all qualified sources
- o Manage worst risks
- o Protect and enhance access
- o Demand Allied reciprocity

Setting quality standards and accepting bids from qualified sources are components of both the Status Quo and Buy World options discussed above. Risk mitigation and access enhancement merit discussion.

Risk Management

Risk management entails the prioritization of the worst risks and then taking steps to mitigate the most threatening risks. The framework constructed in Section Two is one version of the prioritization process. Measures to mitigate the worst risks are several.

The most direct, and in many cases the most cost-effective, risk mitigation strategy is to stockpile. The National Defense Stockpile holds some $10 billion in minerals important to defense production and thought to be vulnerable to disruption. The Strategic Petroleum Reserve holds more than 500 million barrels of crude oil as a hedge against disruption in the oil market. Such stocks enable US firms and the Government to continue to buy and use these minerals on a day-to-day basis with some confidence that a disruption in supply will not quickly cause serious damage to the economy or security of the Nation. The buffer stock suggested and analyzed in Section Three of this paper has the same objective. For a surprisingly small sum of money, the current production of precision guided munitions can be protected from disruptions occurring off-shore. This $15 million represents the insurance premium necessary to protect this production from this particular threat. This protection could also be purchased by adopting the Buy American Strategy, but the cost--the size of the security premium--would clearly be higher.

An alternative to stockpiling is for the Government to purchase standby capacity for use in place of disrupted foreign supplies. This option is increasingly expensive due to the sophistication of today's products and the speed with which they change. It is difficult to justify this expense when the stockpiling option is available.

An option that recognizes the difficulty of the trade-offs among alternative risk mitigation actions is the notion of embedded disruption protection suggested at the end of Section Three. The requirement to maintain the capability to produce through a disruption in foreign supplies would place implementation decisions on individual firms. A firm would evaluate the cost of production protection--stockpiles, excess capacity, alternative domestic sources, alternative foreign sources--and choose the least expensive combination. Unlike the National Defense Stockpile or the Strategic Petroleum Reserve, the Government's role in the implementation would be to specify the coverage required, check compliance, and pay the premium. To the extent that more than one firm bids the contract, competitive pressures will hold the premiums to a minimum.

Stockpiling does not readily apply to the potential problem of technological vulnerability. The hedge necessary to reduce the probability of technological vulnerability is the maintenance of a robust industrial and technological base. Support for scientific and technical research and education is clearly essential.

Enhance Access

In addition to protecting ourselves from the effects of a disruption, we should take actions to reduce the probability of disruption. These are primarily peacetime steps designed to strengthen the links between DoD and its sources of supply.

First, DoD should maintain its goal of obtaining the world's best technology. In most cases this technology is currently resident in the United States: in an increasing number of cases, however, the best technology will reside abroad. Even while we are supporting scientific and technical research in this country, we cannot afford to forego the most advanced technology. Foreign technologies have the potential to make significant contributions to tomorrow's weapons systems--the Japanese contributions to SDI, the Advanced Tactical Fighter and most systems containing semiconductors being the most current examples.

Second, DoD should encourage industrial and technical cooperation among US and foreign firms, including joint research, joint ventures and other business relationships. The strengthening of economic ties between US, Japanese, other East Asian democracies and West European democracies enhances deterrence by presenting the Soviets with a daunting array of interconnected, technically advanced economies. To the extent that armaments cooperation among Allies increases the interoperability and economic returns to scale, fielded Allied weapons systems will be militarily more effective and quantitatively more imposing for the same cost.

Industrial cooperation need not jeopardize the US portion of the Western industrial base that supports US and Allied armed forces. Indeed, such cooperative ventures can provide the leverage to enhance national security. For example, the Fujitsu-Fairchild merger should have been encouraged on national security grounds, and conditions enhancing DoD access to Fujitsu/Fairchild technologies could have been attached. The production of national security-related chips or other equipment could have been required to have been maintained in the US facilities of the merged firm. The access to a firm with both American innovation and security experience and Japanese expertise in quality manufacturing--especially in light of the traditional Japanese corporate reluctance to participate in national security production activities--would have been particularly attractive. It is not at all clear that a domestically-owned, severely weakened Fairchild contributes more to national security than a Fairchild bolstered with an infusion of Japanese capital.

A final access-enhancing measure would be to consider the location of important foreign sources of defense materiel in military force deployment decisions--to deter attacks on foreign sources of supply, to demonstrate to the Allied government our determination to maintain access to its industrial production, and to defend the sea and air lines of communication if deterrence fails.

Conclusions

Vulnerabilities exist, they require action, and actions are available and affordable. They are a small subset of all foreign sources.

Vulnerabilities that jeopardize surge and larger-scale crisis production are problems for contingencies judged in Section Two to be low probability but very high risk--war with the Soviet Union. Further, these vulnerabilities become exploitable under low probability circumstances within these low probability contingencies--extended and near-total cutoff of foreign sources. How much of an insurance premium are we willing to pay to insure continuous production in these scenarios? Several of the policy options--stockpiling a limited number of parts available only from unstable sources--entail reasonable costs. However, strategies such as a pure Buy American strategy, are very expensive.

The vulnerabilities associated with the security of the US technology base, unlike those associated with continuous production, exist across the conflict spectrum. These vulnerabilities are more difficult to deal with because they affect weapons systems and capabilites that do not yet exist. More generalized policy options--support for scientific and technological research and education--are called for here, unless one is willing to attempt some form of defense industrial policy as described at the end of Section Four.

All the scenarios envision some degree of cooperation among the United States and its Allies and trading partners. Although disruptions are possible due to military or political causes, Allied support will likely be available in most cases. Planning for no support from abroad is a waste of resources we cannot afford. Rather than thinking about foreign sources as a problem, one should think about foreign sources as a resource, one requiring actions to hedge against the possibility of disruption, but a valuable resource nonetheless.

Appendix A:

Foreign Sourcing of PGM Subcomponents:Specific Cases

As noted above, foreign sourcing in PGM production can be grouped into five broad categories: subsystems, high incidence subcomponents, integrated circuits, low incidence subcomponents, and materials.

Each is discussed in detail below. Also reported are those subcomponents which are incorrectly identified as foreign source dependencies.

NOTE: In order to protect industry-proprietary information the names of specific contractors have been replaced by letters. A list of contractors referred to is on file at MCDC.

Subsystem Sourcing

Of the eight subsystems discussed below, domestic producers are currently active on seven. Nevertheless, an overseas cutoff would disrupt the production schedules for those fraction of PGMs which rely on the overseas delivery of these components.

Assuring the continuity of production in the face of an unanticipated cutoff would require the prestocking of inventories equal to the shipments lost starting from the cutoff and ending when domestic sources could replace their foreign competitors.

High Incidence Components Sourced Overseas: Data from the JCS study of PGMs shows that five of the top thousand subcomponents are sourced at least partially from abroad.[31] Table A-1 shows the program, the item, the sourcing country, the unit cost, the approximate percentage sourced abroad, the replacement time in months, and the inventory necessary to offset a foreign source cutoff.

In general, US sources could replace overseas components with a two to three month lead time provided that they were operating under wartime conditions, and that, in at least two cases, they had sufficient subcomponent inventories of their own.

Rocket Motor Cases: Three separate programs use foreign producers for rocket motor cases. Table A-2 lists the program, the foreign country, the alternative US source, the unit replacement cost and the inventory of parts required to offset an unanticipated foreign source cutoff.

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31. PGM Study.

Table A-1

High Incidence Components Sourced Overseas
(costs in $,000)

Program	Item	Country	Cost	Months	Pct	Stock
Stinger	Launch Tube	Israel	.11	3	75%	100
Harpoon	Extrusions	Australia	*	2	*	300
HARM	Actuator,	UK	4.5	2/1**	60%	1100
HARM	Gear Motor	UK	0.5	2/1**	60%	100
Standard	Castings	Israel	0.25	3	50%	50
TOTAL						1650

* Represents various extrusions. Total PGM business is roughly $150,000/month

** Two months of assembly, plus one month of parts (prestocking parts is four times cheaper than prestocking item itself)

Table A-2

Rocket Motor Cases
(costs in $,000)

Program	Country	US Source	Unit Cost	Inventory
Harpoon	UK, Australia	A	4.0	600
Skipper	UK	A	0.9	1600
HARM	UK	B	12.0	4800*

* Includes $800,000 for capacity expansion to accommodate increased production to substitute for overseas sources.

For the Harpoon booster rocket motor case, Company A was an active source, but did not receive any FY 86 contracts. If they were provided with prestocked inventory (four months worth at $800 per shipset) it is believed they could begin shipping rocket motor cases in three months under wartime conditions.

Currently, the Skipper rocket motor case is completely sourced overseas but Company A is believed capable of producing the motor it is they are formally qualified. It is estimated that the company could start shipping motor cases within nine months under expedited conditions.

The HARM rocket motor case is sourced 40% domestic, and 60% in the United Kingdom. Although Company B is fully capable of producing the entire lot, it does not currently possess the capacity to do so: furthermore its representatives do not believe they could expand in less than a year or two. Under wartime conditions, additional HARM rocket motors could probably be accommodated by shifting Company B's Patriot work to Company A and the latter's Standard Missile Extended Range rocket motor case work to Companies C and D. Company A itself only runs a shift-and-a-half and has commercial work which could be displaced. However, $800,000 would be needed for certain equipments specific to rocket motor cases. An alternative way of solving the dependency problem would be to provide Company B incentives to modernize its plant with the help of an Industrial Modernization Incentives Program. Such a program was proposed to Naval Sea Systems Command (NAVSEA) but not yet implemented.

It is interesting that this one part, rocket motor cases, should give rise to so much otherwise unrelated foreign sourcing. This may be because the chief overseas source, Royal Ordnance Factory (UK) has established itself as cost-effective over the years.

Rocket Motor Nozzle (for the Standard 2 MR): Company E currently buys its nozzle, a $4000 item, from a single source based in Austria. Cognizant of this dependency, NAVSEA is trying to expedite deliveries under the FY 86 contract and is currently qualifying a source for the FY 87 contract; thus little further needs doing. In its absence, a buffer stock of about two million dollars would be required to cover the year that it would take, so it is claimed, to qualify a domestic source.

Potential Subcomponent Offsets for the Dutch Patriot Missile Purchase In 1985, the Netherlands agreed to buy over a quarter of a billion dollars' worth of Patriot Missiles. Both prime contractors, Companies F and G, however, were required to offset this purchase on a dollar-for-dollar basis. Company F chose to enter into coproduction agreements for power supplies and radar modules on the ground support equipment for a certain fraction of their item buys. This arrangement would not affect the sourcing of missile parts. Company G chose to offset the sales by looking at its corporate buying to shift business to the Netherlands, or creating countertrade arrangements. Again, these offsets would not be used to affect the sourcing of missile subcomponents.

High Incidence Subcomponents

The subcomponents covered comprise the classic foreign source dependency problem. These are widely used items from overseas for which no substitute US source exists. For two of these, silicon field effect transistors (FETs), and ferrite cores, a cutoff could stall production of affected systems for up to a year. A six month impact may be expected from another four, gallium arsenide FETs, precision glass, raw sapphire, and butane triol. The last, high-purity silicon, although used to make

PGMs, is a sourcing but not yet a dependency problem for that sector. Table A-3 summarizes the basic sourcing problems, their applications, their current countries of origin, and the cost of inventory necessary to offset a potential foreign source cutoff.

Table A-3

High Incidence PGM Subcomponents
(costs in ,000$)

Item	Application	Current Source	Inventory
FETs (silicon)	High-frequency radar	Japan	1500
FETs (GaAs)	High-frequency radar	Japan	200
Ferrite Cores	High-frequency radar	Germany	150
Precision Optics	Target Detectors	Japan, Germany	250
Sapphire	Infrared	Switzerland	100
Butane Triol	Rocket Motors	Germany	600
High Purity Silicon	Target Detectors	Germany	000
TOTAL			2800

Field Effect Transistors: Field effect transistors (also known as radio-frequency transistors) come in two types, silicon and gallium arsenide (GaAs). The current high-frequency (over 1 gigahertz) silicon FET market is roughly $40M worldwide, roughly half of which is in the United States market. Of the latter $20M, NEC has roughly half of that market, and about $6M of NEC's United States market is military. Based in part on usage by specific microwave producers, perhaps $1.5 million, or a quarter, goes into PGMs. Potential domestic producers were mentioned as alternative sources: they include Hewlett-Packard, Harris, Micro-Semiconductor, Avantek, Rockwell, General Electric and Raytheon. However, the particular geometries of NEC transistors are design-unique. As a result, it may take up to a year for potential domestic sources to design and perfect NEC's geometries. It may take no longer to alter the basic microwave subsystem configurations to accept domestic geometries. This time would vary greatly by system and geometry. Two companies (H and I) claim that they could replace some types quickly and others in over a year.

Within the last year, gallium arsenide has started to replace silicon as the favored material for making FETs. Domestic producers appear to be more competitive here, but dependencies still exist. One user feels that US producers can make similar devices but with disadvantages in economics, delivery and, to a smaller extent, quality. Another user was dependent but has since gone domestic, except for a $100 GaAs FET supplied by Toshiba ($30,000 annual purchase). MA/COM claims to be the largest GaAs substrate producer in the world; Avantek recently finished a $25M facility and is still growing.

Ferrite Cores: Although there are many domestic producers of ferrite cores (Indiana General, Ferroxcube, Ferronics, Fair-rite, Magnetics Inc.), the market, particularly at its high end, is dominated by Company J. Its advantage stems from the development and use of superior magnetic materials in the gigahertz inductance range. One particular geometry, the low-permeability double-aperture U-60 hexagonal core appears to be virtually irreplaceable by domestic sources at this time. Company J sells roughly $7M worth of all types of cores into the United States at this time, but military sales as such are only a slight percentage of the total. They sell about 1.5 million U-60 cores at $0.10 each. No firm estimate is available on how long it would take a domestic company to replace these products, but a year is a fair guess.

Precision Glass: Precision glass parts, roughly a half a million dollars' worth, are found in detectors for the Sidewinder, the HARM and certain laser-guided missiles. A Japanese company and a German one are the two leaders in the area. The German one (Company K) however, is not always a foreign source, per se: it has a plant here whose basic optics business runs $5M/year. Many users agree with Company K's assessment that it can make everything currently supplied by the Japanese one. Its representatives, at the same time, note that their US plant can produce everything that the West German plant can (certain low-volume domestic orders are sent to West Germany to exploit scale economies). The domestic plant however, depends on overseas sources for $40,000 worth of foreign feedstocks. Company K estimates that it could handle all the overseas glass business within current facilities and could ship within two to three months. However, this capability is dependent on its maintaining a business base for glass optics. Business is declining by as much as 15%/year and its future viability is open to question. If this source is lost, the domestic dependency on glass will be much harder to fix.

Sapphire: Synthetic sapphire is used to make optical elements in the Sidewinder missile, and may have other PGM uses as well. Although there are some domestic sources for finished sapphire, all raw feedstock, most of which is in the form of crackle of scrap material, comes from Europe. One source, from Company L, believes that a domestic plant can be built and operated within six to eight months. It would require roughly seven metric tons of crackle ($400,000) to cover the interim feedstock requirements for the three companies which convert crackle to finished sapphire (Union Carbide, Tyco, and Crystal Systems). This sum, however, would not cover sapphire requirements for bearings (but no such requirements exist for PGMs).

The $100,000 to cover PGM requirements alone is probably well overstated.

Butane Triol: Butane triol is the primary feedstock for BTTN, a critical chemical used in making rocket fuel mixtures. Although some US sources are in stages of development, the current supply comes only from a West German firm, Company M. It claims that although the basic formula is simple, separating the various isomers and maintaining high purity is a difficult art. If the Midgetman ICBM is approved, Company M may source its product domestically; otherwise, in an emergency it could probably do so in 6 to 8 months. Domestic usage of butane triol, all now for PGMs, is roughly 50,000 lbs. a year at $20/lb. Covering an unexpected foreign source cutoff would thus require roughly 30,000 lbs or $600,000 worth.

High-purity Silicon: Roughly $500,000 worth of high-purity silicon is used in the production of detectors. Potential requirements for power switching devices may increase military demands significantly in the future. The world's two major producers (which concentrate mostly on conductor-grade silicon) are Wacker (West Germany) and Topsil (Denmark). DoD's requirements are now being met by domestic sources and inventory drawdowns. Texas Instruments mostly serves its own needs. Martin Marietta has bought foreign high-purity silicon in the past but now possesses a stockpile of intermediate size. Company 14, which sells mostly to another single firm, Texas Optoelectronics, came on stream quickly a few years ago, but some time was required for buyer and vendor to work towards some acceptable quality. This problem is now solved and overall process yields have returned to what they were when Wacker was the sole supplier of the domestic market.

The continuity of the domestic high-purity silicon supply may be imperiled in two ways. The first is that neither source is guaranteed to stay on-line (e.g. Texas Instruments may not maintain production if the volume of Paveway laser-guided bomb work dwindles.) The second is that the supply of polysilicon rods, the feedstock for high-purity silicon, is intermittent. Current supplies are being drawn from an inventory created for a one-time purchase of small-diameter (25-50mm) rods. When this runs out, the only way to get small-diameter surfaces (used in PGMs) will be to process the occasional (roughly once a year) large-diameter rods which happen to pass tight purity specifications. It is not clear that such processing will not itself produce impurities. At present DoD is working a purchase guarantee for small-diameter rods so that they can be produced on demand and forestall a potential foreign source dependency. In the absence of this capability, the supply of small-diameter plate of adequate specifications may take several months to recover. An inventory of $100,000 of polysilicon rods at that point should otherwise be adequate.

Integrated Circuits (ICs)

Among subcomponents, no ICs are themselves made abroad but the industry, in general, has so many foreign source dependencies that a cutoff would hurt production severely. The key question is whether enough of the industry would be left to ensure that military production would be continued.

The IC industry now depends on overseas facilities to assemble its finished chips from domestically produced wafers. Also sourced from overseas are most of its ceramic packages, much of its plastic feedstock and metal parts for non-ceramic packages, a high fraction of its silicon wafer, and all the raw glass used to make glass masks. Assembly capacity is the most salient. All other problems could be handled by stockpiling piece parts and materials: costs would be pennies on the dollar. The assembly operation, since it occurs almost last in the process, could only be mitigated by prestocking the entire chip. This would cost money.

Calculations for the entire industry, however, show that except for some types of packages, the industry could meet military needs in isolation without further investment. A cutoff would still leave enough industry to cover current military needs three times over. The dependency issue, however, cannot be dismissed so quickly because of its pervasiveness and the adverse trends now being observed.

Assembly: Almost all domestic IC operations, while based on domestic wafer fabrication, assemble the chip overseas where labor is much cheaper. Most military circuits are also packaged overseas: only a certain fraction, "38510" chips, have to be completely produced at home.

To assess the adequacy of the leftover domestic assembly base required knowing both military demand to domestic capacity. Military demand was derived by muitiplying the nation's monthly chip sales, 300-350 million units, by the percentage purchased by DoD, the latter estimated (by Texas Instruments analysts) at just over four percent. This percentage was confirmed by many others. The product, roughly 14 million units, represented the capacity which had to be found.

The first places examined in compiling this 14 million chip capacity were the small military-oriented assembly shops maintained by domestic producers to "38510" work. Most such operations are working well below capacity now and could easily expand production in emergencies. Many companies surveyed, could, in fact, meet their own requirements in this way and have room for other requirements besides. Among those surveyed, Company O could do about three million/month; Companies P, Q, and R, two million/month; and Companies S and T combined could do one million/month. The total for these six facilities is 10 million/month. Extrapolating this to the entire military chip business (e.g. Fairchild (California), National, Signetics, Raytheon, etc.) suggests that the current "38510" facilities could get to at least 14 million/month.

Added to this are a few commercial houses that have retained domestic assembly capability. The independent domestic assembly business could probably handle 11 million/month based on the capacity of its leading independent, Company U. Other potential sources include Company V at 15 million/month and Companies W and X at 9 million/month. Sixty million chips/month capacity appears easily available at home in an emergency.

IBM, which itself accounts for roughly 20% of all domestic production, assembles most of its circuits in-house. Its capacity, however, relies in a proprietary flip-chip process which is largely incompatible with the wafers produced by the merchant semiconductor houses. Some convergence between the two is likely in emergencies but not without a lead time of six months.

Beyond that, most respondents indicate that they could reestablish domestic packaging capability within six to twelve months.

Using such capacity, needless to add, requires that military chips be assembled on domestic lines. By and large this is no problem for the "38510" facilities which already make military chips. The commercial facilities would be similarly capable if the military would accept plastic rather than ceramic packaging for an interim period.

Amassing 14 million chips'/month worth of military specification (MILSPEC) burn-in and test capacity is more problematic and may not be possible. Most industry respondents, however, maintain that MILSPEC standards are overstated and may even result in less quality than available commercially.

<u>IC Packages</u>: Almost all MILSPEC ICs have to be packaged in ceramic, most of which comes from two Japanese companies. One of them has a domestic facility and its representatives claim that its own facilities, coupled with those of other domestic sources, create a sufficient base of supply to support the ceramic package needs of government in an emergency. They also say that their own facility could be operated without requiring materials from overseas. Furthermore, the current domestic ceramic package technology base is capable of producing all package types required. Figures provided suggest that its gross capacity to make ceramic packages exceeds the capacity of domestic assemblers to use them.

Another solution, particularly for assemblers not doing military work now, would be to package circuits in plastic as commercial operations do. While circuits, so packaged, may lose their current hermeticity (and even that is open to dispute), this is of minor importance in emergency conditions when PGMs would not sit around long enough to be spoiled before they were used.

At the same time, though, a high percentage of both plastic and metal leads is sourced overseas. Only one of the three major domestic assemblers surveyed used a domestic plastic source and then only partially. Roughly half of the metal leads used by the three were domestic. Neither plastic nor leads are impossible to make and if US capability is not sufficient, it could be made so quickly. Nevertheless, at roughly a cent per chip each for plastic and leads, some prestocking to cover the roughly 10 million chips used in PGMs would be a low cost insurance policy.

Another possible package dependence is metal can packages for transistors. Two respondents originally reported a dependency for metal can packages. One has eliminated its foreign sourcing, but the other still buys at least part of its line overseas. At least two domestic sources have been located which are now producing these metal cans, one of which could expand production many-fold by displacing commercial business. Another two producers could do so easily (if not immediately) but are making more sophisticated devices at present.

Silicon Wafers The domestic IC industry imports a high percentage of its raw silicon. There are now two domestic sources, Monsanto (which was reported looking for a buyer) and Siltec, which has been recently purchased by a Japanese concern. In addition, both Wacker (German) and Topsil (Danish) have domestic facilities but import feedstock to run them. One PGM supplier, Signetics, reported a dependency on silicon wafers to a Texas Instruments survey on its HARM suppliers but it could meet its requirements from domestic sources if the need arose.

Glass Mask Blanks Glass masks are the medium on which an IC design is etched so that it can be used in photolithography. A typical chip uses eight to fourteen different masks in its production. At present all the feedstock glass used in making the masks is produced in Japan, mostly by Hoya. Since the annual market is roughly $50 million, one can estimate that the military market requires roughly $2 million, and PGM production perhaps $100,000 to $200,000. Were Japanese sources cut off, however, the effect would not be immediate. Glass masks can be used over and over again; they are needed only when bringing out new designs or expanding production to new photolithography lines. There is no inherent reason why current PGM circuits cannot continue using the glass masks they are now produced with. Without new glass, however, new designs cannot be processed, but some domestic producers, such as Corning, are capable of producing raw glass masks and moving down the learning curve in quality. Some prestocking for contingencies may be prudent.

Low Incidence Subcomponents

There were several cases of a single respondent reporting that it was purchasing a critical subcomponent overseas. Although none of them suggested a widespread dependence the item, certain provisions would have to be made to avoid major schedule disruptions from an unanticipated foreign source cutoff. Table A-4 lists the buyer, item, foreign source, and buffer stock cost associated with seven instances.

Table A-4

Low Incidence Subcomponents from Overseas

Respondent	Item	Source	Inventory
Y	Ball screws	UK	$ 30,000
Z	Copper-liner forms	Switzerland	$ 250,000
AA	Bearings	Unknown	$ 10,000
BB	Molybdenum foil	Austria	$ 2,000
CC	PWB plating bath	UK	$ 50,000
DD	Springs, pivots	Germany, South Africa	$ 1,000
EE	Radome chemicals	Germany, Mexico	$ 50,000
TOTAL			$ 393,000

Ball Screws: Ball screws, a $150,000 annual buy item for the Patriot missile program, were previously dual-sourced on a 70:30 split between a British source, and a domestic one (Company FF). The British source now has 100% of the current buy, but the domestic source could return to production within three months under emergency conditions.

Copper-liner Preform: Copper-liner preform, a $100 item for the Copperhead program, is currently purchased from Switzerland. The impact of a cutoff is to return to drawn-and-carried liners made in-house; a transition could be made in six months (or less, given the assurance of the respondent that this purchase is not really a dependence).

Bearings: Foreign off-the-shelf bearings, costing $2-$3 each, are used in making a slip ring assembly for the Standard Missile 2 program. In an emergency, American bearings would be quite acceptable, and could be delivered within two months.

Molybdenum Foil: Between $5,000 to $10,000 worth of foil from Austria is used on the Patriot program annually. Although there are domestic sources, foreign ones are cheaper. A cutoff could be domestically replaced in a few months.

Plating Bath: The copper-based printed-wiring board (PWB) operations of Company CC buys its plating bath (roughly one million dollars' worth) from a European source (probably British). Although such baths are, in general, produced domestically, the particularly chemistry is produced only by a foreign company (with US laboratories). Using US sources would feature lower yields but an acceptable product. No estimate was made of how long a transition would take, but it is probably short. Only a small fraction of its PWB operations are used to make PGMs. The buffer stock estimate of $50,000 generously covers the fraction (1/10th) of the capacity used for PGMs and assumes a six-month replacement period.

Diamond Pivots and Precision Hairsprings: Pivots and hairsprings are low-cost ($5) items purchased from abroad to make the Phoenix missile accelerometer. The diamond pivot is made domestically but uses South African diamonds. The precision hairsprings are purchased from Germany for historic reasons but could be replaced by domestic sources in six months. Total usage of both items runs $500/month.

Radome Chemicals: Dependencies were reported for three chemicals: titania, arsenic pentoxide, and magnesium oxide. Titania, a particular grade of titanium dioxide, a whitener, is now bought from German sources, but alternative facilities in Norway and Canada could produce the product in two to three months. Arsenic pentoxide can be purchased from Canadian plants, and thus is not foreign-sourced per se. Magnesium oxide is purchased from Mexico because the particularly purity available there. Domestic sources could be used but because of quality reasons, considerable retrofit would be needed first.

Materials

Several respondents cited raw materials as items for which they are dependent on overseas sources. Mineral problems are the province of the National Defense Stockpile and, for that reason, separate costs to cover the PGM industry have not been calculated. To cover the PGM industry alone in any of the four material mentioned would be cheap.

A fuller discussion of the domestic supply-demand status of these materials is provided in the case study on materials supply.

Samarium: A rare-earth, samarium is used by Company GG to make permanent samarium-cobalt magnets used in motors and actuators. Military sales are 10 to 25 percent of its total business.

Germanium: Company HH uses germanium to make interlace actuators for the IR Maverick missile. Current supplies come from Africa via Belgium.

Indium: Two respondents reported at least some indium-based dependencies. One was partially dependent on overseas sources of indium antimonide; the other was completely dependent on indium arsenide but only for a PGM program (the Rolling Airframe Missile) not yet in production.

Palladium One capacitor producer, Company II, uses $3 million worth of palladium in its electrostatic inks.

Incorrect Identification of Foreign Sourcing

There were a few respondents that incorrectly identified a component as foreign source dependent when it was either sourced at home or was not used in military systems. Much of the confusion was the failure to distinguish between foreign-owned but US-located facilities and facilities located abroad. Three respondents to the Navy's FY 86 Production Base Analysis identified dependencies which on closer examination affected only their commercial and not PGM products. Getters, which were mentioned twice as a foreign sourced item, are actually produced in Colorado by the US subsidiary of the Italian firm, Saes Getter.

Many rocket motor chemicals were also misidentified. Some, like TMETN, DEGDN, and Desmodur N-100 are produced locally, the latter by a domestic subsidiary of a German company. Zirconium carbide, although sourced abroad, could as easily be purchased in the United States. PBNA, a component of the Sparrow rocket motor, is produced only in Poland, but current stockpiles at Naval Ordnance Station, Indian Head (MD) cover current requirements through 1988. Beyond that, in an emergency, requirements are sufficiently small to allow laboratory-scale production, given environmental waivers.

APPENDIX B:

Calculating Metals Supply And Demand

Demand: The demand for metals was calculated by estimating the ratio of wartime demand to peacetime demand for each of 540 industrial sectors covered in the Commerce Department's input-output table. This ratio was then applied to the tonnage that each sector used for each metal to calculate total demand. Where specific information on metals usage per unit weapon was available, it was used as a partial substitute for Department of Defense (DoD) requirements.

The basic calculations used to estimate scenario demand come from using an input-output table, a device which translates final demands into intermediate ones. An example of final demand is a customer buying a car. An example of intermediate demand is General Motors buying steel for the car, US Steel buying coal to make steel, etc. If General Motors buys equipment to manufacture cars, however, this is investment, not intermediate demand. The reason is that, unlike the direct relationship between products and components, there is no one-to-one relationship between investment expenditures and production volume.

The input-output table used is a bench mark table originally derived from the 1977 Census of Manufacturers. This table says how many dollars of steel mill products, for example, were used by car-makers. It does not say how many tons of steel were used to make cars, a non-trivial difference. Data in the table can create estimates of how much of every dollar used in car-making found its way to steel-making, both directly and indirectly, through other products (e.g. steel-belted radials). 540 sectors are represented, down to the three and four-digit Standard Industrial Classification (SIC) level.

This bench mark table was then updated with preliminary 1982 Census of Manufacturing data by Margaret Buckler McCarthy of the Interindustry Economic Research Fund, Inc. (under contract to FEMA's Larry Salkin). This process reassigned all flows less than $1.75 million to a new sector, "unimportant industry", leaving 29,000 non-zero entries, or half.

The final demand estimates were, in turn, updated to 1985 data for this study. First, final demand was segregated into six classes: consumer personal expenditures, gross private fixed investment, defense expenditures, other Government, exports and imports. The first four classes were then adjusted to reflect increases in demand from 1982 to 1985 using the National Income and Product Accounts and applied to roughly thirty broad industry groupings. Imports rose in proportion to the increase in consumption and investment final demand (except for textile imports which were increased disproportionately). Exports, though, were held constant in real dollars (except for agricultural commodities which were reduced 30 percent). As it turned out, this admittedly crude method gave a reasonable macro approximation of trade trends between 1982 and 1985.

The numbers were then reformatted to take advantage of the particular characteristics of the IBM PC family and a short, fast (90 seconds) program was written in the computer language "C" (available on request) to generate intermediate demands (e.g. how many dollars of steel) given a vector of final demands (e.g. how many dollars of cars). This process was run for the actual 1985 economy.

To build the wartime scenario, certain classes of final demands (e.g. defense purchases) were increased and others (e.g. consumer durables) were decreased corresponding to Table 12 in the main text. Imports and exports were eliminated because North America was assumed to be cut off. (This created some large increases in the demand on a few sectors because so much of their potential demand was repatriated.)

Table B-I illustrates how the input-output table can be used to generate metals demand based on tonnage-per-sector estimates developed by the Institute for Defense Analyses for DoD's MDIEMS model.

Table B-1

Estimating Scenario Metals Demand from Input-Output Data: A Sample Demonstration

	DEMAND			METALS USAGE		
Sector	1985	Scenario	Ratio	Baseline		Scenario
Plumbing	2.03	1.06	0.52	4000	(* .52=)	2080
Fasteners	7.38	9.45	1.28	3000	(*1.28=)	3840
Tanks	3.64	23.30	6.40	3000	(*6.40=)	19200
TOTAL				10000		25120

Cross-multiplying the baseline metals usage per sector by the ratio of scenario to actual demand per sector yields scenario demand by sector, which, when summed, is the total scenario demand. The ratio between total scenario demand and baseline demand (2.51) was then applied to the 1985 apparent domestic demand as estimated by the Bureau of Mines to determine the scenario demand used in the supply-demand analysis.

Aerospace requirements for certain metals were calculated by multiplying unit aircraft metals content (collected by the Joint Aeronautical and Materials Advisory Committee) by peak aircraft production rates. This total was multiplied by 1.2 to represent aircraft types not surveyed and then by 1.5 to reflect the ratio of material purchased to material used. These numbers were substituted for the aircraft and engine data generated by the input-output tables. Ammunition requirements were also so adjusted.

Finally, an estimate for North American demand was made (because the supply comparison is with the North American, not just the US, base). This required adding 10% to US demand to represent Canada and 5% to represent Mexico. When the basis for comparison included Central and South America an additional 25% was added to demand. For metals whose usage outside the US was known to be very small (e.g. titanium), no adjustments were made.

Supply: Metals production in North America was forecast as a combination of full capacity operations plus recycled supply.

Capacity data was taken from the Bureau of Mines publication, Minerals Facts and Problems: 1985 Edition, and updated several years to 1987 by industry experts in the Bureau. It was assumed, unless they otherwise indicated, that production could reach capacity levels quickly provided that demand for co-products of high-demand minerals was itself sufficiently high.

Recycled supply was estimated to equal the highest level experienced over the last several years, assuming that the high metals prices that war creates would spur maximum recycling.

The difference between scenario demand and total supply (primary supply plus recycling) was characterized as leftover demand. Leftover demand had to be supplied either from additional primary supply or stocks (recycling was assumed at maximum to begin with). Where mining was the bottleneck, prospects were estimated from known but under- or undeveloped mines. In other cases, processing capacity was deficient. A consistent estimate for new processing capacity under emergency conditions was in the 1 1/2 to 2 year range.

Comparing supply and demand generates some measure of shortfalls in the war scenario. The last step was to estimate how long the existing stockpile of minerals and metals would last in covering the shortfall, and how dependent the United States was on the world outside North America. Vulnerability was assessed by taking the source of supply into account, with Western Hemisphere sources in general considered more accessible than those across the oceans.

Caveats: Using input-output tables is the best way to estimate demand under alternative scenarios. However, in the context of comparing military versus commercial demand, they are subject to systemic errors arising from the lack of sufficient disaggregation in the model and use of dollars to simulate material flows.

Take aluminum. Using the input-output table to estimate the impact of the war scenario on how much money is spent on aluminum generates an increase of 35%. Recalculation in tonnage terms yields an increase of 10%. If the demands for military and commercial aircraft are separately calculated, the resulting calculations show a fall of 5% in aluminum demand. Why the difference? In the scenario the demand for aluminum rises in military aircraft, stays constant in wide-bodied aircraft, and falls in construction. The aircraft industry pays almost twice as much for its aluminum than the construction industry does, so that a shift of 100,000 tons (and no net increase) from one to the other translates roughly into a decline of $100 million in construction aluminum and an increase of $200 million in aircraft aluminum, or a net gain. So it seems that more tons of aluminum are demanded when it is only the average cost which is rising. Additionally, commercial aircraft use a lot more aluminum per dollar than military aircraft do. If both increase at the same rate, the usage of aluminum will increase proportionately. But if, as happens in war, military aircraft increase disproportionately, the demand for aluminum will not rise by so much.

To see another problem of disaggregation, take zinc, used by auto makers in nonferrous forgings to make car parts. In a war the amount of money going into nonferrous forgings rises sharply, but it does so to buy aircraft parts, which use very little zinc. Car parts production drops. The multipliers used in input-output tables, however, assume that a rise in nonferrous forgings automatically mean a rise in zinc demand.

In some cases both military and commercial sectors use what are ostensibly the same items, but whose construction, and hence materials usage, differs sharply. Military and commercial customers both buy semiconductors, but the military likes theirs packaged in ceramic, rather than plastic. A shift in the type of semiconductor demand is lost in the input-output tables and fails to reflect large increases in ceramics requirements as a result.

Finally, input-output tables do not allow one to predict investment requirements as a function of changing output levels. The wartime scenario assumes no changes in overall investment (certain categories aside). This may be true in aggregate but certain specialty items such as test equipment and machine tools may undergo a several-fold increase in requirements, both with implications for material demand. This may understate the requirement for tungsten, for instance, almost a third of which is used for metal-cutting tools.

In general, input-output tables tend to exaggerate the impact of military spending on physical output. Military customers require quality-testing, documentation and, at times, more exotic capabilities. This adds cost but not weight. Military customers, for instance, account for 9% of all integrated circuit sales by dollar, but only 4% by volume. A shift in demand from commercial to military uses within intermediate sectors usually means less material per dollar used. Input-output tables, by not reflecting this change, overstate materials usage.

Increases in defense spending, however, lead to disproportionate increases in hardware production. In peacetime, military production is generally too small to be done at peak efficiency. If the Air Force bought 100 F-16s a month, their individual price tags would be lower than they are now. If the basic rule-of-thumb (double production and unit costs fall 20%) holds over that range, an eight-fold quantity increase would allow costs to drop fifty percent. Thus a fourfold increase in expenditures should lead to an eight-fold increase in production. At some point, though, economies of scale are realized and few advantages from cumulative learning are possible. (Indeed the use of new producers, as is necessary in wartime, vitiates the benefits from cumulative learning until much later in the production cycle). The location of this point is anyone's guess; but it usually lies beyond current rates.

The demand calculations used in this report try to take this factor into account by using a relatively high production rate for aircraft and conceding the lack of scale economies (given the current overcapacity) in ammunition production and shipbuilding. As such, the best guess, considering all caveats, is that the methodology used overstates the military demand for materials, but by how much is unknown.

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